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Verification of Technical Analysis Rules using Matlab

Ověření pravidel technické analýzy s využitím SW Matlab

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2. Description of Matlab
3. Description of Technical Analysis
4. Verification of Technical Analysis in Matlab
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Declaration of Utilisation of Results from the Diploma Thesis
List of Annexes
Annexes

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The declaration

“I hereby declare that I have elaborated the entire thesis including annexes myself.”

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1. Introduction

Technical analysis is the study of prices in freely traded markets with the intent of making profitable trading or investment decisions. The main instruments which are used in technical analysis are charts, indicators and trading rules.

The goal of this thesis is to verify technical analysis based on the historical trading data of EUR/USD currency pair and the historical trading data of the stock of Alibaba Group Holding Ltd.

This thesis is divided into 5 chapters. In chapter 1, there is the introduction, which briefly introduces the structure and content of the whole thesis.

In chapter 2, we make the descriptions of Matlab, a proprietary programming language developed by MathWorks Company of America, and it is the main tool which we use in our analysis in this thesis. In this chapter, we introduce the basic operations of Matlab, and we also describe the programming structures and graphing principles in Matlab.

Chapter 3 is a theoretical part of description of technical analysis. We introduce the most widely used methods in technical analysis, such as the trend analysis, the support and resistance, charts and chart patterns and technical indicators. At the end of this chapter, the Automated Trading System (ATS) is also defined and described.

In chapter 4, we make the verification of technical analysis based on two cases, and there are three types of indicators applied in this chapter, they are Moving Average (MA), Bollinger Bands and Relative Strength Index (RSI). We choose the best strategies in the in-sample period and apply them in the out-of-sample period to verify whether technical analysis works or not under some specific assumptions.

In chapter 5, we summarize the results which we get from the analysis in chapter 4, and we also make the conclusion of the whole thesis.

2. Description of Matlab

Matlab is the abbreviation of Matrix Laboratory, it is a proprietary programming language developed by MathWorks Company of America. As the advanced technical computing language and interactive environment, it is used for algorithm development, data visualization and data analysis. It can be also applied in the technical analysis, risk assessment and other financial fields. The computation part of this thesis is based on the work of Matlab, therefore, it's necessary to know the features and operations of Matlab. In this chapter, Matlab is introduced based on Johnson (2002) and Alfio and Fausto and Paola (2006).

2.1 Introduction of Matlab

Matlab, Mathematica and Maple, are also known as the three major mathematical softwares. Matlab integrates the numerical analysis, matrix computing, data visualization, modeling and other functions in one window environment, providing a comprehensive solution for scientific research and engineering design. And to a large extent, it has broken away from the editing mode of the traditional noninteractive programming language. Matlab represents the advanced level of international scientific computing software.

Matlab can perform matrix operations and drawing functions. It is mainly used in engineering computing, signal detection and processing, image processing, financial modeling and other fields. The basic unit of data for Matlab is a matrix, whose instruction expression is very similar to the usual forms of mathematics and engineering, so it is much simpler to use Matlab to solve problems than to do the same things in languages such as C, FORTRAN and so on. What's more, Matlab also absorbs the advantages of other software such as Maple, which makes Matlab a powerful mathematics Software.

2.2 Basic Operations in Matlab

In Matlab software, there is a main window which consists of four parts, they are the command window, workspace, command history and current folder. We show this in Figure 2.1.

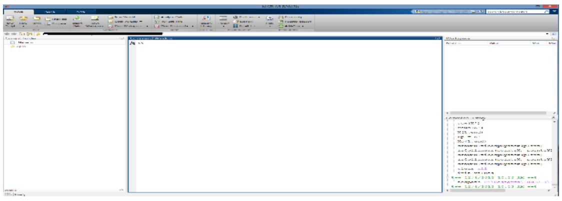

Figure 2.1 Main window in Matlab

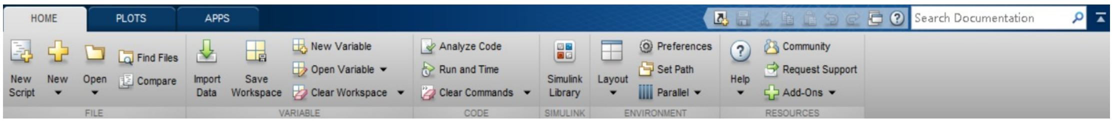

Figure 2.2 Home menu of Matlab

In the top of the main window, there is the home menu, we show it in Figure 2.2. Home menu includes file, variable, code, Simulink, environment and resources menu. In the file menu, we can see some options like *new* and *open*, the *new* is used for opening a new file, and the *open* is used to open the existing files such as M file, fig file, mat file, mdl file and cdr file. In the variable menu, there are options like *import data*, *save workspace*, *new variable*, *open variable* and *clear workspace*. In the code menu, the options are used for the analysis of potential errors of codes and making improvements of them. Simulink provides an integrated environment for dynamic system modeling, simulating and graphical analysis. Simulink is designed for system controlling, signal processing, etc. It can work with linear and nonlinear systems, as well as discrete and continuous systems.

2.2.1 Command Window

In the command window, we can input commands in it, and then results of calculations are shown. Once we make any mistake in the command, Matlab can show us the wrong parts of that command and also offer us the advice to correct it. There are some operators and special characters which are often used, see Table 2.1. In Table 2.2, there are some frequently used commands in Matlab command window.

Table 2.1 Operators and special characters

Operator	Function
+	Plus; addition operator
-	Minus; subtraction operator
*	Scalar and matrix multiplication operator
.*	Array multiplication operator
/	Division operator
./	Array division operator
^	Scalar and matrix exponentiation operator
.^	Array exponentiation operator
[ ]	Brackets; enclosure array elements
( )	Group operation; identify specific components
,	Comma; separate statement and elements in a row
;	Semicolon; separate columns and suppresses display
:	Generates matrices; indicate all rows or all columns
%	Show a comment in an M- file
%%	Cell divider

Table 2.2 Commands in Matlab command window

Command	Function
clc	Clear command window
clear	Clear variables in workspace
delete	Delete file in disc
help	Search help information about command
which	Search the folder of specified file
disp	Show the variable
Ctrl+P	Call the last line command
Ctrl+N	Call the next line command

2.2.2 Workspace

All variables from data are listed in workspace, and the information like the variables' name, value, class are also shown in it. To edit variables, we can double click the variable and then edit it. The variables in workspace will be deleted after exit Matlab. In table 2.3, we list some relevant commands in workspace.

Table 2.3 Relevant commands in workspace

Command	Function
clear	Clear variables from workspace
disp	Display variable value
who	List all variables in workspace
whos	List all variables in workspace with sizes and types
load	Load all variables in specified file into workspace
save	Save all variables into default file
size	Show the size of variable
length	Show the length of variable
matfile	Change variables into MAT-files,

2.2.3 Command History

The historical statements which users have run are shown in the command history window, and the commands that run as a group are shown by the brackets in the left. By default, Matlab automatically saves command history files after each command is executed, however, editions to values in the variable editor are not included in the command history.

If there is any error in the historical command, it will be indicated as a color mark. The historical commands can be executed again and they can be copied into the command window to create the M file directly. All historical commands are kept until they are deleted by users, or they will be deleted automatically when the number of commands in the history file exceeds the specified limit number. By default, in the command history, 25,000 commands can be saved.

2.2.4 Current Folder

In the operation of Matlab, we need to load files from the current folder and then execute commands. Current folder is used to browse the current work path. The current work path is the work directory in the runtime of Matlab. We know there contains a lot of toolboxes in Matlab, and users will also generate many files when using Matlab, and from the work path, we can open and use these tools, functions and files in Matlab. Comparing with some other software which set the default work path in the C drive, the current folder in Matlab brings more convenience.

2.3 Matlab Programming Structure

MATLAB language, as a special programming language, it is available for the users to write new programs. When we write a program in Matlab, we should effectively use the program control structures. There are three types of program control structures, they are sequential structure, loop structure and branch structure. Below, we make descriptions of the application of these structures in Matlab programming.

2.3.1 Sequential Structure

The sequential structure is the simplest program structure. After users write the program, the system will follow the steps in the program in turn. There is a simple example of sequential structure in Figure 2.3.

```
>> a=[19 62 73];
b=[46 57 96];
c=a+b

c =

    65   119   169
```

Figure 2.3 A example of sequential structure

2.3.2 Loop Structure

Matlab programming language provides various control structures that allow for more complicated execution paths. For example, there are some situations when users need to execute a block of code several times, and the loop structure allows us to execute a command or a group of commands multiple times.

Matlab provides various types of loops to handle looping requirements, which include *while* loops and *for* loops. Below we introduce them with examples separately.

a) While loop

The *while* loop repeatedly executes statements while a specified condition is true. The syntax of a *while* loop in Matlab is shown in Figure 2.4, and we also make an example of *while* loop in Figure 2.5.

```
while <expression>
    <statements>
end
```

Figure 2.4 Syntax of a while loop in Matlab

```
>> num=0;EPS=1;
while (1+EPS)>1
    EPS=EPS/2;
    num=num+1;
    end
>> EPS

EPS =

    1.1102e-16
```

Figure 2.5 An example of while loop

b) For loop

In a *for* loop, the commands between *for* and *end* statements are executed in cycles. The syntax of a *for* loop in Matlab is shown in Figure 2.6. An example of *for* loop is shown in Figure 2.7.

```
for index = values
  <program statements>
  ...
end
```

Figure 2.6 Syntax of a for loop in Matlab

```
>> sum=0;
   for n=1:10;
   sum=sum+n;
   end
>> sum

sum =

    55
```

Figure 2.7 An example of for loop

2.3.3 Branch Structure

The execution of branch structure is to choose the execution path based on certain condition, rather than strictly following the order of statements. The key to the programming method of branch structure is to construct appropriate branch conditions and analyze program flow.

The branch structure is suitable for the calculation with logic or relation comparison. When designing this kind of program, we should draw the program flow chart first, then write the source program according to the program flow chart, so that making the problem simple and easy to understand. There are two types of branch structure, they are *if* structure and *switch* structure. The syntaxes of *if* structure and *switch* structure are shown in Figure 2.8 and Figure 2.9.

a) *If* structure

```
If <expression 1>
  <statement 1>
Elseif <expression 2>
      <statement 2>
Elseif <expression 3>
      <statement 3>
 …
Elseif <expression N>
      <statement N>
Else <statement N+1>
End
```

Figure 2.8 Syntaxes of *if* structure

In the *if* structure, the calculations are classified according to different conditions, and the condition is shown after the term *if*. For different conditions, there are corresponding different calculation statements. We list all conditions in the structure to complete the whole calculation.

b) *Switch* structure

```
Switch <expression>
   Case <constant 1>
         <Statement 1>
   Case <constant 2>
         <Statement 2>
   …
   Case <constant N>
         <Statement N>
   Otherwise
         <Statement N+1>
   END
```

Figure 2.9 Syntaxes of *switch* structure

The *switch* structure is a control structure that extends the functionality of the *if* structure. In a *switch* structure, the object is to compare with a number of given values and one or more statement sequences are executed.

2.4 Matlab Graphing Principles

By using the functions of graphing in Matlab, we can plot two-dimension and three-dimension graphs. We show the methods of plotting graphs by using Matlab with examples in this part. The commands for colors in the plotting are listed in Table 2.4, and the commands for types of lines are listed in Table 2.5.

Table 2.4 Commands for colors

Color	Command
Red	r
Green	g
White	w
Blue	b
Black	k
Yellow	y
Pink	m

Table 2.5 Commands for types of lines

Type of line	Command
Actual line	-
Dotted line	--
Colon line	;
Point line	.

If we need to add titles for the graph, we should use the *title* command which allows to add a title to the graph, and the *xlabel* and *ylabel* commands which generate labels along *x-axis* and *y-axis*. What's more, the *grid* command allows us to add the grid lines in the graph and the *axis square* command generates a square plot.

2.4.1 Plotting Two-Dimension Graphs

To plot the two-dimension graph of a function, we should take the following steps:

1) define the independent variable *x*, by specifying the range of values for the variable *x*, for which the function is to be plotted;
2) define the function, *y = f(x)*;
3) call the plot command, as plot *(x, y)*.

We make an example of plotting a two-dimension graph of a function, the commands are shown in Figure 2.10, and by executing the commands, we can get the graph in Figure 2.11.

```
x = [-100:20:100];
y = x.^2;
plot(x, y)
```

Figure 2.10 Commands of plotting a two-dimension graph (example)

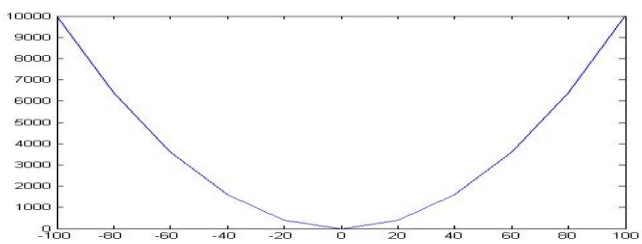

Figure 2.11 An example of a two-dimension graph

2.4.2 Plotting Three-Dimension Graphs

We make an example of plotting a three-dimension graph in the following content, the commands for plotting are shown in Figure 2.12 and the graph is shown in Figure 2.13.

```
>>  [X,Y] = meshgrid(-8:.5:8);
R = sqrt(X.^2 + Y.^2) + eps;
Z = sin(R)./R;
mesh(Z);
```

Figure 2.12 Commands of plotting a three-dimension graph (example)

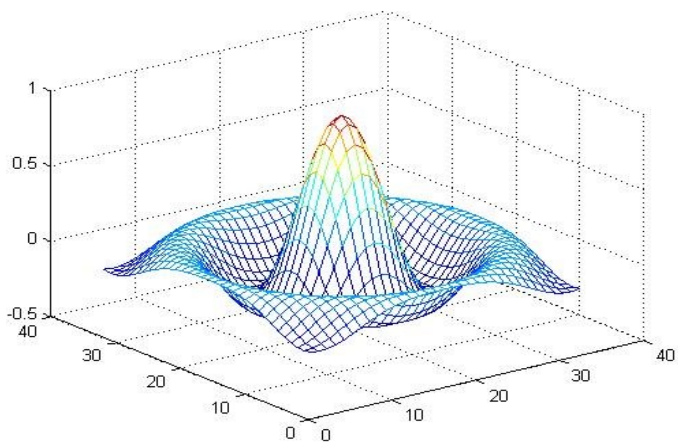

Figure 2.13 An example of a two-dimension graph

3. Description of Technical Analysis

In this chapter, we make description of technical analysis. Firstly, we describe three analytical approaches in financial markets based on their definitions. Secondly, we introduce the most widely used methods in technical analysis. Thirdly, the Automated Trading Systems (ATS) are defined and described.

3.1 Description of Analytical Approaches in Financial Market

There are three main analytical approaches which help investors to make profitable decisions in the financial markets. They are fundamental analysis, psychological analysis and technical analysis. In Table 3.1, we make the comparation of these three approaches from different aspects. And in the next parts, the descriptions of them are made with more details.

3.1.1 Fundamental Analysis

Fundamental analysis, in accounting and finance, is the analysis of a business's financial statements (usually to analyze the business's assets, liabilities, and earnings), health, and its competitors and markets. Fundamental analysis is an approach which is used to evaluate a security by measuring its intrinsic value, it focuses on the examination of related economic, financial, qualitative and quantitative factors. For macroeconomic factors, there are interest rates, employment rates, GDP; for microeconomic factors, there are financial conditions and management of the selected company.

Different from psychological analysis and technical analysis, when analyzing a security, currency or other financial derivatives, there are two basic methods which are used in fundamental analysis, they are bottom up analysis and top down analysis.

The goal of fundamental analysis is to calculate the intrinsic value, which helps to compare with a security's current price when the investors make decisions. At the same time, the intrinsic value also indicates whether the security is undervalued or overvalued. What's more, fundamental analysis is also a way to evaluate the management and make internal business decisions of a company.

Table 3.1 Comparation of three approaches

	Fundamental	Psychological	Technical
Definition	Calculating intrinsic value based on economic factors	Track market behavior of individuals based on psychological theories	Forecasting future price movements based on historical data
Type of trade	Long term investment	Short term speculation	Short or medium term investment
Advantage	A comprehensive view of the business, financial health and future development	Allows a quick response to a great mass of investors' behavior	Responds faster than fundamental analysis
Disadvantage	Rich experience of analysts is required	Possibility of poor estimation of reactions of other investors	False signals, the subjectivity of analysts, not applicable to long-term investment

3.1.2 Psychological Analysis

Most conventional economic theories are based on the assumption that all individuals taking part in an economic activity are behaving rationally, however, in most cases, this assumption doesn't reflect how people behave in the real world. The fact is that people frequently behave irrationally, and their behavior is challenged by risk aversion, this kind of performance belongs to the field of behavioral finance.

Behavioral finance studies the effects of psychological, social, cognitive, and emotional factors on the economic decisions of individuals and institutions and the consequences for market prices, returns, and resource allocation, although not always that narrowly, but also more generally, of the impact of different kinds of behavior, in different environments of varying experimental values. The typical behavioral characteristics in the financial market are loss aversion, mental accounting, narrow framing, anchoring and overconfidence.

In a word, psychological analysis aims to track market behavior by accounting for the beliefs, desires and fears of investors. This type of approach holds that most important information available is a way to understand how the great mass of investor will behave, because that will essentially determine the basic fluctuations of the market.

3.1.3 Technical Analysis

In its basic form, technical analysis is the study of prices in freely traded markets with the intent of making profitable trading or investment decisions. [1] Unlike fundamental analysis, technical analysis does not focus on the intrinsic value of a stock, the only thing that matters is to forecast the future directions of prices movements based on a security's past trading data, primarily prices and trading volumes or index values. Technical analysts study the action of the market itself, which disregards all other psychological factors, they believe that "the market is always correct."

The main instruments which are used in technical analysis are charts, indicators and trading rules. The description of these instruments with details are shown in the next parts.

[1] Arson (2007)

a) History of technical analysis

Technical analysis appeared hundreds of years ago. The oldest known example of technical analysis is a trading method used by Japanese rice traders in 18th century, which has evolved into the use of candlestick chart, and nowadays, candlestick chart has become one of the leading tools in technical analysis.

Charles Dow is considered as the "father" of modern technical analysis and he was also one of the founders of The Wall Street Journal[2]. In the early period of the development of technical analysis, the charts analyzing is the most widely used method, Charles Dow reportedly originated a form of point and figure chart analysis, and he also created the Dow Jones Industrial Index, which is a stock market index that shows how 30 large publicly owned companies based in the United States have traded during a standard trading session in the stock market.

Dow theory inspired the development of modern technical analysis at the end of the 19th century. And there are also other pioneers of technical analysis, which include Ralph Nelson Elliott, William Delbert Gann, Richard Wyckoff and so on. In recent decades, more technical tools and theories have been developed and enhanced under the developing computer-assisted techniques.

b) Assumptions of technical analysis

There are five key assumptions in technical analysis, which are shown as follows.

1. The market discounts everything. This assumption means the prices have already reflected all relevant information.
2. Price moves in trends. This means after a trend has been established, the future price movement is more likely to be in the same direction as this trend rather than against it.
3. History tends to repeat itself. The repetitive nature of price movements is attributed to market psychology, which means market participants tend to provide a consistent reaction to similar market stimuli over time.
4. Market value of the asset is a reflection of supply and demand of the asset. Supply

[2] Sheffrin (2003)

and demand are driven by different factors, such as economic data, risk aversion and so on.

3.2 Methods of Technical Analysis

In this part, we introduce the most widely used methods of technical analysis, they are trend analysis, support and resistance, charts, and technical indicators.

3.2.1 Trend Analysis

There is a saying in technical analysis, it's "Don't buck the trend", which tells people how an important role trend analysis plays.

A trendline is a simple charting technique that adding a line to a chart to represent the trend of a security in a market. It is formed when a line can be drawn between a minimum of three or more price pivot points. Trend lines are commonly used to decide entry and exit timing when trading securities. We show it in Figure 3.1.

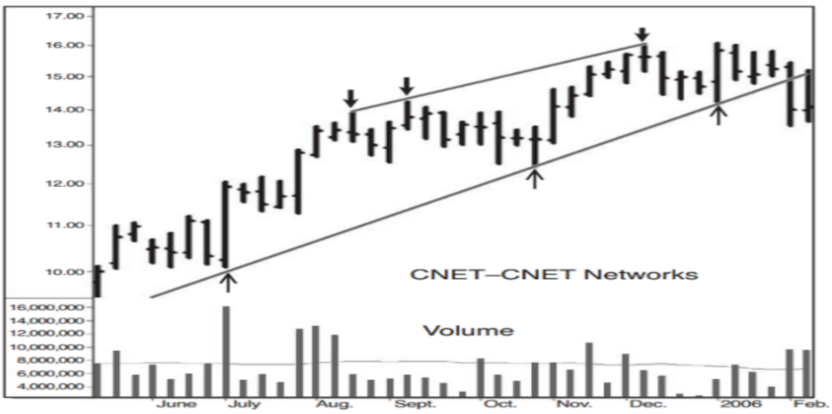

Figure 3.1 An example of trendlines

Source: Kirkpatrick and Dahlquist (2010, p. 14)

And trend channel, which is defined as an area between two parallel trendlines. We can also see it in Figure 3.1. It is usually used to measure a trading range. The upper trendline connects the highest prices, and the lower trendline connects the lowest prices.

In the Dow Theory, there are three concomitant trends in the market, they are the primary trend, the secondary trend and the minor trend. In the next part, here we make the descriptions of them.

a) Primary trend

The primary trend is the overall direction of the market which can last for years, it is most predictable. It is always an uptrend (the price movement of a financial asset when the overall direction is upward) or a downtrend (the price movement of a financial asset when the overall direction is downward).

A primary uptrend means there is a “primary bull market”, it is characterized by three separate phases: The first represents reviving confidence from the prior primary bear market; the second phase represents the response to increased corporate earnings; and the third is when speculation becomes dominant and prices rise on “hopes and expectations.”

A primary downtrend means there is a “primary bear market”, it is also characterized by three separate phases: first, abandonment of hopes upon which stocks were purchased; second, selling due to decreased earnings; and third, distress selling, regardless of value, by those who believe the worst is yet to come or who are forced to liquidate.

b) Secondary trend

As we mentioned, the primary trend is the general direction for prices, however, sometimes there exits opposite directions of that of the primary trend, which we call it “retracements”, it usually lasts for several weeks or months. This is the secondary trend. Because of its unpredictability and shorter time frame, Dow believes it’s risky to make profits based on the considerations of a secondary trend.

c) Minor trend

The minor trend is the result of the daily or weekly fluctuations due to the imbalance of supply and demand over short period of time. Because the instantaneous supply-demand imbalance is difficult to predict, Dow Theory believes it’s too risky to make investment decisions based on the minor trend. Here is an example of the three concomitant trends in Figure 3.2.

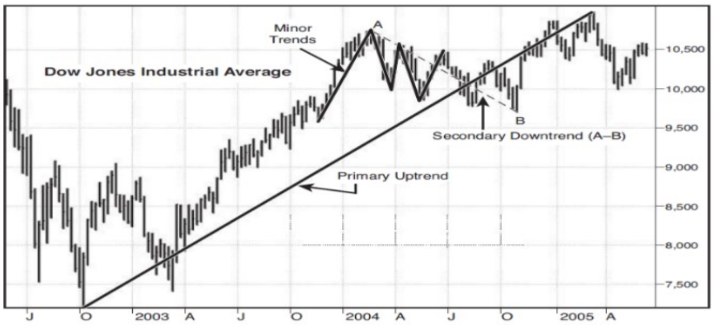

Figure 3.2 An example of three concomitant trends

Source: Kirkpatrick and Dahlquist (2010, p. 80)

3.2.2 Support and Resistance

When prices have been rising and then reverse downward, the highest point in the rise is referred to as a resistance point, and at the level of that point, sellers are as powerful and aggressive as the buyers and halt the rise. If the sellers (supply) become more powerful and aggressive than the buyers (demand), there will be a price decline from the peak. A resistance level becomes a resistance zone when more than one resistance level occurs at roughly the same price. Prices rarely rise and stop at exactly the same level.

A support point is the opposite of a resistance point, it is a single trough. At the support level, buyers become as powerful or aggressive as the sellers and halt a price decline.

The concept of support and resistance presumes that prices will stop at these recorded levels or zones in the future, so they represent a remembered psychological barrier for prices. The zones will carry through time and become barriers to future price actions.[3] In Figure 3.3, we show an example of support level and resistance level. Not only will the zones carry through time, but also, once they are broken through, they will switch functions: previous support will become resistance, and previous resistance will become support.

[3] Arson (2007)

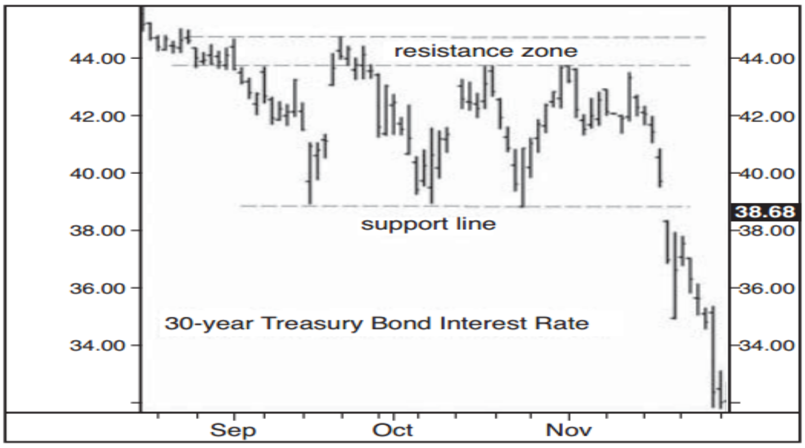

Figure 3.3 An example of support level and resistance level

Source: Kirkpatrick and Dahlquist (2010, p. 235)

3.2.3 Charts and Chart Patterns

In this part, the method of technical analysis based on the uses of charts and charts patterns are introduced. In the contents below, we also make classifications of them separately.

A. Charts

Four primary types of charts are introduced with figures in this part. They are line charts, bar charts, candlestick charts, and point and figure charts.

a) Line chart

This is one of the most basic types of chart in chart analyzing, because in the line chart, only the closing price is plotted for each successive day, and there are no intraday price movements shown in the chart, that's the result of many investors think the closing price is more important than the opening, high, or low price within a given period. There is an example of line chart in Figure 3.4, it is the line chart of the daily closing prices of DJIA, S&P 500, and NASDAQ Composite (daily: June 30, 2006–June 29, 2010).

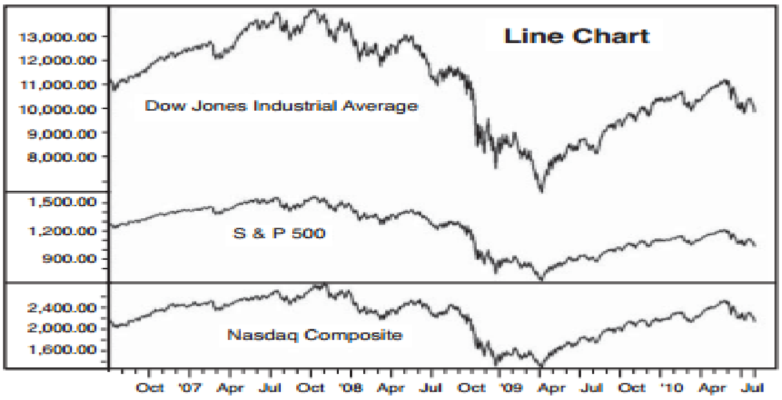

Figure 3.4 An example of line chart

Source: Kirkpatrick and Dahlquist (2010, p. 208)

b) Bar chart

This type of chart shows vertical lines that indicates the price range in the given period of time, because comparing with line chart, there is the addition of opening, highest and lowest price in the in it. The closing price is displayed on the right side of the bar, and the opening price is displayed in the left side. In Figure 3.5, there is an example of a single bar. And in Figure 3.6, an example of bar chart is shown.

Figure 3.5 An example of a single bar

Figure 3.6 An example of bar chart

Source: Kirkpatrick and Dahlquist (2010, p. 210)

c) Candlestick chart

Candlestick chart originated in Japan in 18th, now it's very popular among traders and investors. Comparing with a bar chart, the price range and the closing and opening price are also shown in a candlestick chart, and the difference is that the body of the candlestick also indicates important information. That is, the longer the body is, the more intense the trading pressure, and conversely, short candlesticks indicate less price movements. What's more, if the color of the body is white (or green), it means the closing price is higher than the opening price, if the color of the body is black (or red), it means the closing price is lower. We show these rules in Figure 3.7. And an example of candlestick chart is shown in Figure 3.8.

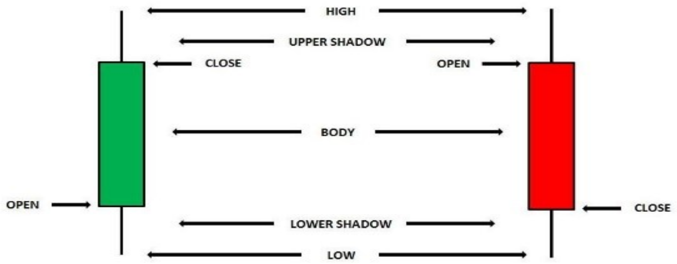

Figure 3.7 An example of a single candlestick

Figure 3.8 An example of candlestick chart

Source: Kirkpatrick and Dahlquist (2010, p. 212)

There are some special candlesticks, like Marubozu, Spinning Tops, Doji, etc. For example, Marubozu is a kind of candlestick which doesn't have upper or lower shadows (The thin vertical bars, representing the price extremes of the trading session, are called the shadows). White (or green) Marubozu means the closing price equals to the highest price and the opening price equals to the lowest price, which indicates that buyers controlled the price action. Black (or red) Marubozu means the closing price equals to the lowest price and the opening price equals to the highest price, this indicates the sellers controlled the price action. We show this situation in Figure 3.9.

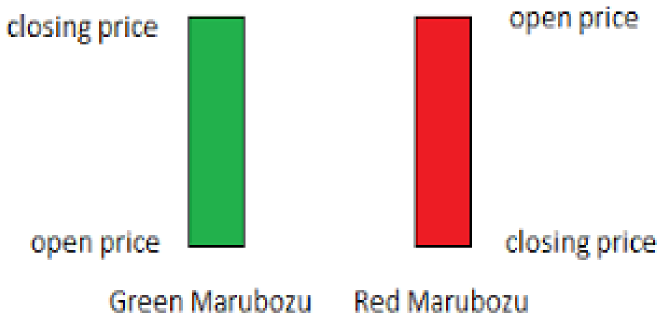

Figure 3.9 Marubozu

d) Point and figure chart

Point and figure chart is a study of pure price movement, it is also called a “P&F” chart. It uses rising columns of X’s and descending columns of O’s to represent these price movements. Point and figure chart is not widely used by the average investor, but it has a long history of use dating back to the first technical traders. We show an example of point and figure chart in Figure 3.10.

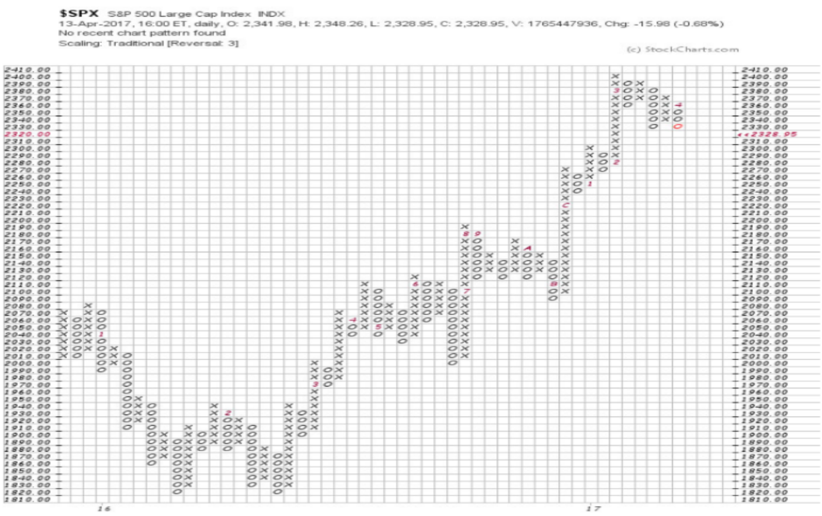

Figure 3.10 An example of point and figure chart

Source: Kirkpatrick and Dahlquist (2010, p. 566)

B. Chart Patterns

The term “chart pattern” is a distinct formation on a stock chart that creates a sign of future price movements. Chartists use these patterns to identify current trends and trend reversals, which indicate the buying and selling signals.

There are two types of patterns, they are reversal and continuation. A reversal pattern signals that a previous trend will reverse after the completion of the pattern, and a continuation pattern signals that a previous trend will continue once the pattern is complete.

a) Head and shoulders

The Head and Shoulders is a reversal chart pattern that indicates a reversal of the trend once it's completed. There are four elements in this type of pattern, they are a left shoulder, a right shoulder, a peak and a neckline.

A Head and Shoulders Top, which means the middle peak is the highest one (head) and the two others are lower and roughly equal (shoulders). The connection between these peaks is a trend line (neckline) that represents the key support level to watch for a breakdown and trend reversal. A Head and Shoulders Bottom means an inverse of the Head and Shoulders Top, because the neckline is a resistance level to watch for a breakout higher. We show them separately in Figure 3.11 and Figure 3.12.

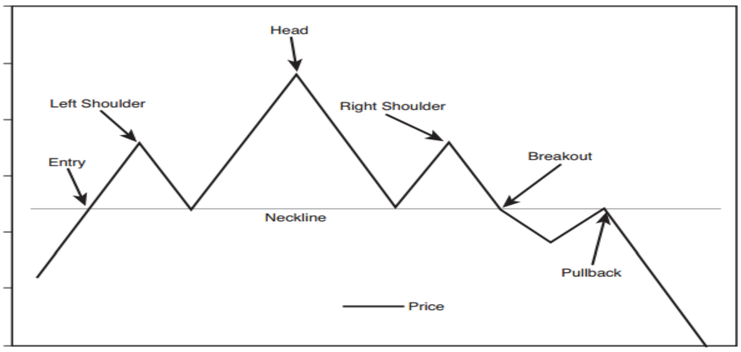

Figure 3.11 Head and shoulders top

Source: Kirkpatrick and Dahlquist (2010, p. 327)

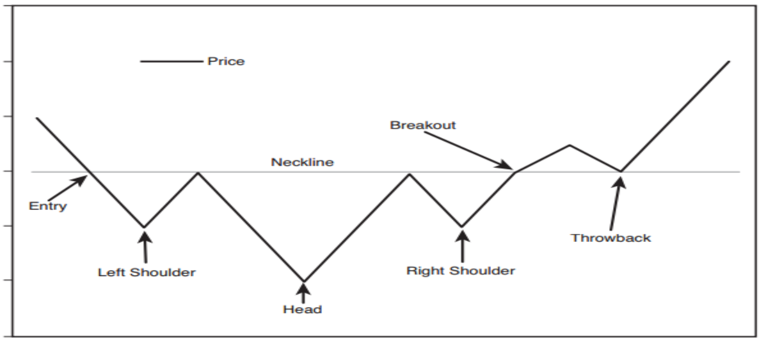

Figure 3.12 Head and shoulders bottom

Source: Kirkpatrick and Dahlquist (2010, p. 328)

b) Cup and handle

The Cup and Handle is a bullish continuation pattern. Once an upward trend has paused, there will be a continuation of the previous trend till its completion. The “cup” means there is a part of the pattern which has the similar shape of “U”, just like a cup. The “handle” means there is a short pullback on the right side of the cup in the chart pattern, which has the similar shape with a handle. After the handle is complete, the stock may breakout to new highs and resume its trend higher. There is an example of Cup and Handle in Figure 3.13.

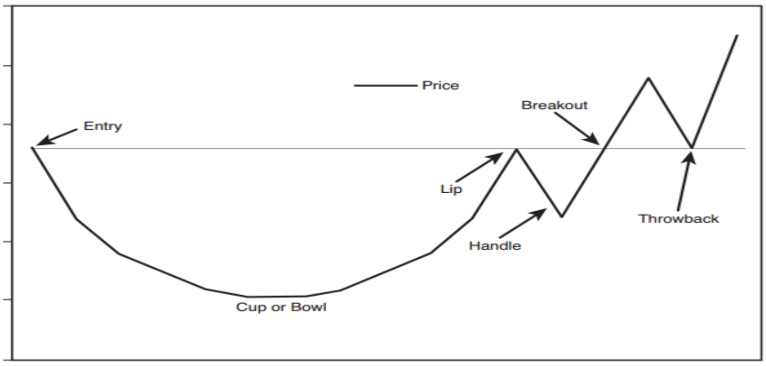

Figure 3.13 Cup and handle

Source: Kirkpatrick and Dahlquist (2010, p. 326)

c) Double tops and bottoms

The Double Tops or Double Bottoms chart pattern is one of the most popular chart patterns by traders. It is a reversal chart pattern. It means there is a sustained trend when the same support or resistance level appeared twice without a breakthrough. An example of Double Tops is shown in Figure 3.14.

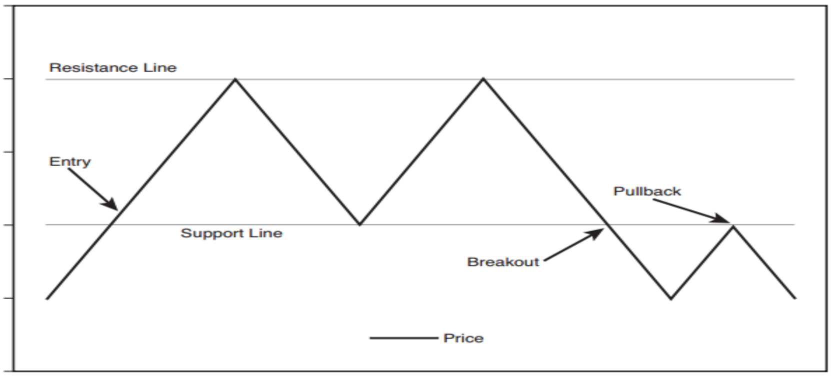

Figure 3.14 Double tops

Source: Kirkpatrick and Dahlquist (2010, p. 310)

d) Triangles

Triangles is a reversal chart pattern, the trading period of triangles usually lasts from weeks to months, it can be the result of an upward-sloping lower bound or a downward sloping upper bound. Thus, there are a number of possible combinations of the two bound lines.

When the lower trend line is rising and the upper bound is a horizontal resistance zone, it is called an ascending triangle. We show it in Figure 3.15. When the lower bound is a horizontal support zone and the upper is a downward slanting trend line, it is called a descending triangle. We show it in Figure 3.16. When the upper bound is declining and the lower bound is rising, it is called a symmetrical triangle. We show it in Figure 3.17.

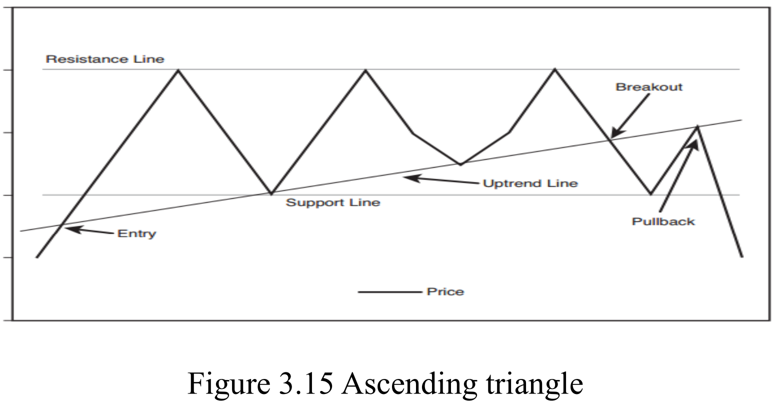

Figure 3.15 Ascending triangle

Source: Kirkpatrick and Dahlquist (2010, p. 317)

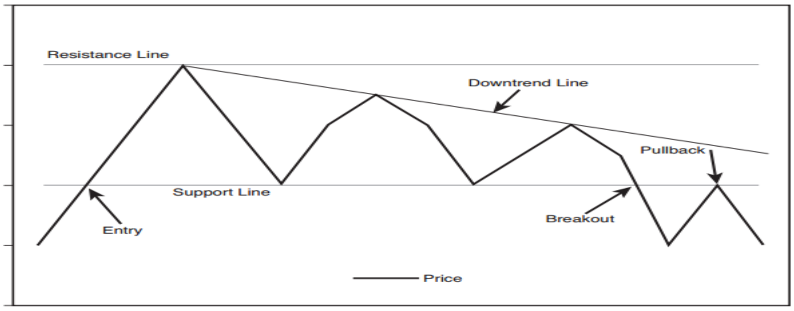

Figure 3.16 Descending triangle

Source: Kirkpatrick and Dahlquist (2010, p. 316)

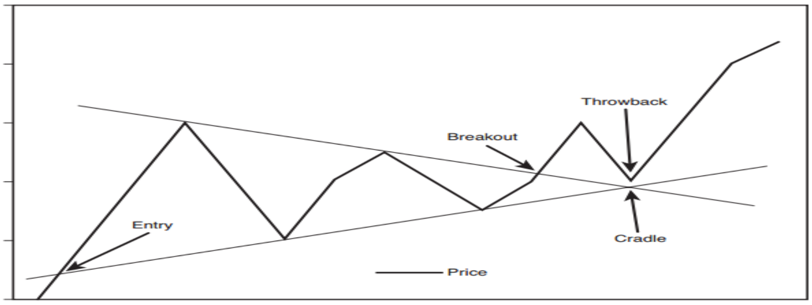

Figure 3.17 Symmetrical triangle

Source: Kirkpatrick and Dahlquist (2010, p. 318)

3.2.4 Technical Indicators

In this part, we introduce four important indicators in technical analysis, they are Moving Average (MA), Moving Average Convergence Divergence (MACD), Relative Strength Index (RSI) and Bollinger Bands.

a) Moving Average (MA)

Moving Average is a widely used indicator in technical analysis that helps smooth the price action by filtering out the “noise” from random price fluctuations. It’s not the prediction of price’s direction, but it defines the current direction with a lag due to the calculation on past data. The most important uses of moving averages are to identify the trend direction and to determine support and resistance levels. What’s more, it is also the basis for other technical indicators, such as the Moving Average Convergence Divergence. The typical types of moving averages are the Simple Moving Average (SMA) and the Exponential Moving Average (EMA).

Simple Moving Average (SMA)

A simple moving average is the calculation of the sum of prices of a security divided by specific number of periods. Most moving averages are based on closing prices. For example, a 5-day simple moving average is the five-day sum of closing prices divided by five. The formula of its calculation is shown as follows:

$$SMA = \frac{\sum_{n=1}^{N} P_n}{N}, \quad (3.1)$$

where N is the number of periods, P is the price.

Exponential Moving Average (EMA)

Exponential moving averages avoid the lag by applying more weight to recent prices. The weighting applied to the most recent price depends on the number of periods in the moving average. Different from simple moving averages, a given day's EMA's calculation depends on the calculations of EMAs for all the days prior to that day.

In the calculation of EMA, firstly, the initial EMA value is equal to the value of initial price. Secondly, we need calculate the weighting multiplier. Thirdly, we calculate the EMA for each day based on the previous EMA value and today's closing price and the multiplier. The multiplier is calculated as follows:

$$K = \frac{2}{N+1}. \quad (3.2)$$

The value of EMA for each day is calculated as below:

$$EMA_n = P_n \cdot K + EMA_{n-1} \cdot (1 - K), \quad (3.3)$$

where K is the multiplier.

b) Moving Average Convergence Divergence (MACD)

MACD is about the convergence and divergence of the two moving averages. Convergence occurs when the moving averages move towards each other, and divergence occurs when the moving averages move away from each other. The MACD is calculated by subtracting the 26-day EMA from the 12-day EMA. There is an example of MACD in Figure 3.18.

Figure 3.18 An example of MACD

Source: www.stockcharts.com

As for the signal line, 9-day EMA, there is a MACD histogram represents the difference between MACD and it. If the histogram is positive, it means the MACD line is above its signal line, vice versa. We show this in Figure 3.19. The values of 12, 26 and 9 are the typical setting used with the MACD, other settings can be substituted which depends on different trading goals.

Figure 3.19 MACD line and its signal line

Source: www.stockcharts.com

c) Bollinger Bands

Bollinger bands is a type of technical analysis indicator that was developed by John Bollinger in the 1980s, it is a developed technique of using a moving average with two trading bands above and below it. Unlike a percentage calculation from a normal moving average, Bollinger bands simply add a standard deviation calculation, standard deviation is used to measure the volatility and show how the stock price vary from its true value.

Many traders believe the closer the prices move to the upper band, the more overbought the market, and the closer the prices move to the lower band, the more oversold the market. There is an example of it shown in Figure 3.20.

Figure 3.20 An example of Bollinger Bands

Source: www.stockcharts.com

We can see the Bollinger bands consist of three lines, the middle one is a measure of the intermediate-term trend, usually a simple moving average, that serves as the base for upper band and lower band. The interval between the upper band and the lower band is determined by volatility, which is represented by standard deviation of the same data that were used for the calculation of SMA. When the markets become more volatile, the bands widen, and vice versa. And the calculations are shown as follows:

$$MB = SMA_{20}, \tag{3.4}$$

$$UB = SMA_{20} + 2 \cdot \sigma_{20}, \tag{3.5}$$

$$LB = SMA_{20} - 2 \cdot \sigma_{20}, \tag{3.6}$$

where MB is the middle band, UB is the upper band, LB is the lower band, SMA_{20} is the “20 day” simple moving average, and σ_{20} is the “20 day” standard deviation of price.

d) Relative Strength Index (RSI)

Relative Strength Index (RSI) is a measurement of the speed and change of price movements. RSI oscillates between zero and 100. Traditionally, and according to Wilder, RSI is considered overbought when above 70 and oversold when below 30.

The calculations of RSI can be shown as follows:

$$RSI_t = \frac{AG_t}{AG_t + AL_t} \cdot 100, \tag{3.7}$$

where the AG_t is the average gain and the AL_t is the average loss.

The period of calculation of RSI is usually set to 14 days, which is the default suggested by Wilder in his book. And losses are expressed as positive values, not negative values. Here we show an example of RSI in Figure 3.21.

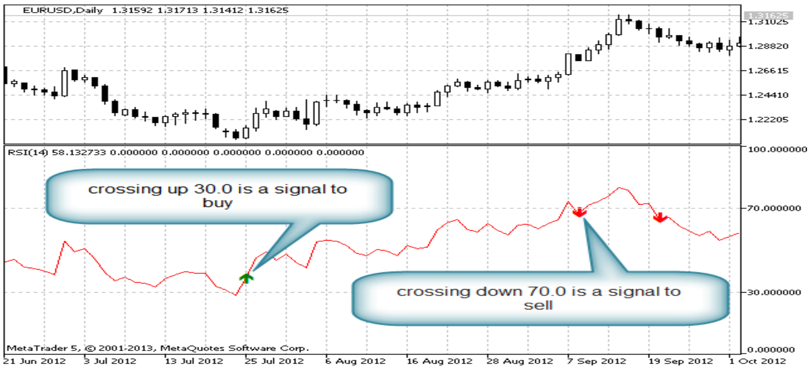

Figure 3.21 An example of RSI

Source: www.stockcharts.com

3.3 Automated Trading Systems

In this part, we make the descriptions of Automated Trading System (ATS) based on trading rules of different technical indicators which we introduced in part 3.2.4. In the contents below, first of all, the automated trading system is defined.

An automated trading system is a computer program which automatically generates orders based on predefined set of rules. In technical analysis, it is an exactly defined procedure suggesting whether to buy, sell or do nothing to an asset at a certain period.

3.3.1 Trading Rules

We set the automated trading systems based on the trading rules of moving average (MA), Bollinger bands and relative strength index (RSI).

a) Trading rules of moving average

A trading rule can be generated by two moving averages, one is called fast moving average which is related to prices over short period of time, and the other one is called slow moving average which is related to prices over long period of time. Here we make the abbreviations of them as $MA(f)$ and $MA(s)$, and the trading rule can be defined as follows,

$$decision_t = \begin{cases} \text{buy, if } MA(f)_t > MA(s)_t \text{ and } MA(f)_{t-1} < MA(s)_{t-1}, \\ \text{sell, if } MA(f)_t < MA(s)_t \text{ and } MA(f)_{t-1} > MA(s)_{t-1}, \\ \textit{do nothing otherwise}, \end{cases} \tag{3.8}$$

the formula above represents a simple automated trading system.

b) Trading rules of Bollinger bands

We have introduced the meanings of the middle band (*MB*), the upper band (*UB*) and the lower band (*LB*), and its trading rule is, if the price of asset continually touches the *UB*, it means the price is thought to be overbought, triggering a sell signal; conversely, when it continually touches the *LB*, the price is thought to be oversold, triggering a buy signal. We show this rule in the following formula,

$$decision_t = \begin{cases} \text{buy, if } P_t < LB_t, \\ \text{sell, if } P_t > UB_t, \\ \textit{do nothing otherwise.} \end{cases} \tag{3.9}$$

c) Trading rules of relative strength index (RSI)

As we mentioned, according to Wilder, RSI is considered overbought when above 70 and oversold when below 30, which can also generate the signals to buy or sell,

$$decision_t = \begin{cases} \text{buy, if } RSI_t < 30, \\ \text{sell, if } RSI_t > 70, \\ \textit{do nothing otherwise.} \end{cases} \tag{3.10}$$

3.3.2 Setting Automated Trading Systems

Based on the trading rules we have set above, we can see there are three possible positions in our trading, they are long (when we buy the asset) and short position (when we sell the asset), and moreover we should consider the neutral position (when we neither buy nor sell), we can set the automated trading systems based on these positions, which 1 for long position, -1 for short position and 0 for neutral position. We show this in formula (3.11),

$$position_t = \begin{cases} 1, \text{ if } \textit{long position}, \\ -1, \text{ if } \textit{short position}, \\ 0, \textit{ otherwise}. \end{cases} \tag{3.11}$$

3.3.3 Profitability of Automated Trading Systems

In the verification of technical analysis, the key step is to analyze whether the investors make profits if they follow the automated trading system. So, in the following formulas, we show the method of calculating the profits which are generated during the trading.

Firstly, we should calculate the returns r_t, which is shown as a percentage changes of prices,

$$r_t = \frac{P_t - P_{t-1}}{P_{t-1}} \ , \tag{3.12}$$

secondly, we can compute the wealth the investor would have possessed at time *t* if he or she followed the ATS,

$$w_t = w_0 \cdot \prod_{i=1}^{t} [(1 + position_i \cdot r_i) \cdot (1 - fee \cdot |position_i - position_{i-1}|)], \tag{3.13}$$

where w_0 is the initial value which we usually set to 1, *position* is the position taken according to formula (3.11), *r* is the return which we can get from formula (3.12), and the *fee* represents transaction costs stated in percentage which are incurred on buying and selling orders.

4. Verification of Technical Analysis in Matlab

In this chapter, we make the verification of technical analysis in Matlab based on two cases. In the first case, we verify technical analysis by using the historical data of EUR/USD currency pair. In the second case, we verify technical analysis by using the historical data of Alibaba stock. There are three technical indicators applied in these two cases, they are Moving Average (MA), Bollinger Bands and Relative Strength Index (RSI).

4.1 Case 1-EUR/USD Currency Pair

In case 1, we make the verification of technical analysis based on the historical trading prices of EUR/USD currency pair. In the following parts, firstly, we describe the input data, then, we use the data to make some calculations, at last, we make conclusions from the calculations' results.

4.1.1 Input Data

We describe the input data which are used in this case. Firstly, the basic characteristics of the target currency pair which we analyze are introduced. Secondly, we make the assumptions in our verification. At last, we show the development of the historical trading prices and also calculate the returns of them, and the results of calculations are used in the later analysis.

a) Descriptions of the target currency pair

The dataset we apply in the verification is the daily closing prices of EUR/USD currency pair. The EUR/USD currency pair is the abbreviation for the euro and U.S. dollar pair. The currency pair indicates how many U.S. dollars (the quote currency) are needed to purchase one euro (the base currency). Trading the EUR/USD currency pair is also known as trading the "euro". For example, if the pair is trading at 1.50, it means it takes 1.5 U.S. dollars to buy 1 euro. The EUR/USD is affected by factors that influence the value of the euro or the U.S. dollar, for example, when the Fed intervenes in open market activities to make the U.S. dollar stronger, the value of the EUR/USD will decline due to a strengthening of the U.S. dollar compared to the euro.

b) Assumptions in the verification

In our verification, we assume that initial wealth w_0 is equal to 1$. In the European and American foreign exchange markets, the transaction costs are usually within the range of 0.2% to 0.5% both for buying and selling orders of EUR/USD.

When it comes to the transaction costs, there are two terms which have to be mentioned, one is the "spread", the other one is the "slippage". During our trading, we should know the transaction costs can certainly vary from different brokers. In general, the spread is the difference, expressed in pips, between the broker's buying and selling prices for any given commodity, share of stock or currency pair. Usually, the greater the interest or popularity the instrument is, the smaller the spread might be. As for the slippage, it occurs when the price of an instrument changes from the moment we put in the order to buy or sell to the moment when the order is executed.

In Table 4.1 we list the current spread of EUR/USD trading based on the information of main foreign exchange brokers in the world, and according to this, in our verification, we make three assumptions of the transaction costs, the first one is set to 0.2%, the second one is set to 0.5%, and the third one is set to 0%, that transaction costs are equal to 0% means there is no cost incurred during the trading.

Table 4.1 Spread of EUR/USD trading

Foreign exchange brokers	**Spread of EUR/USD trading**
FXCM	0.0003
FxNet	0.0002
FXGrow	0.0004
ForexClub	0.0005
DF Markets	0.0005

Source: www.investing.com/currencies/eur-usd

c) **Input data and calculations of returns**

We download the data from the website www.investing.com. The period of applied data is selected from May 5th, 2003 to November 27th, 2017. The whole sample size is 4,559. We divide the data into two parts, they are in-sample period and out-of-sample period. In in-sample period, the duration of data is from May 5th, 2003 to August 16th, 2010, and in out-of-sample period, the duration of data is from August 17th, 2010 to November 27th, 2017. So, each part approximately accounts for 50% of the whole period. We show the data of each part as well as the calculations of returns of them in Figure 4.1.

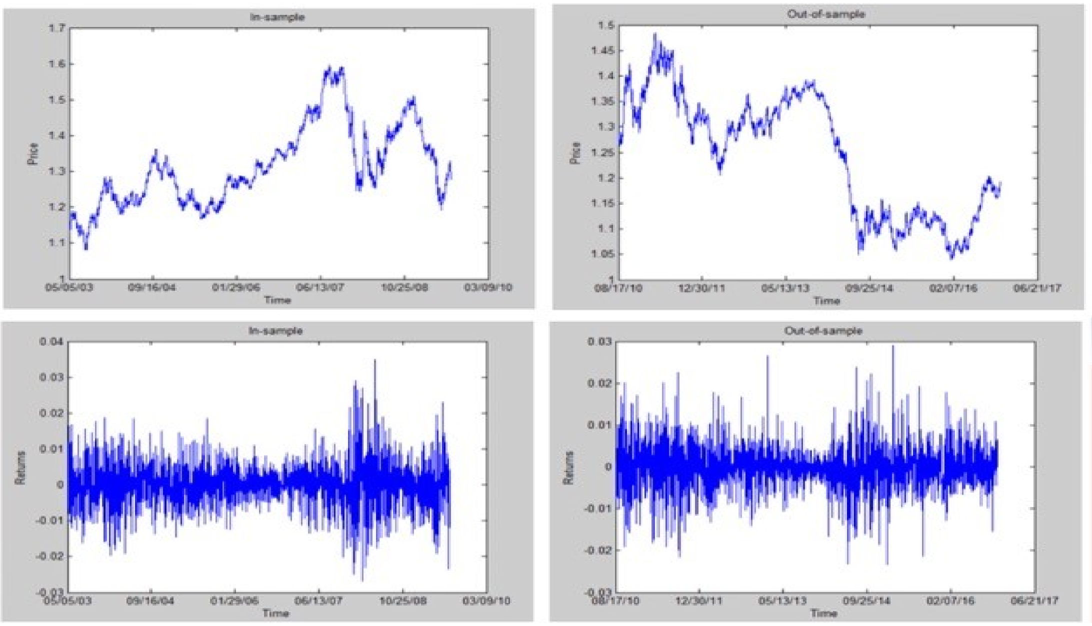

Figure 4.1 Closing prices of EUR/USD trading and the returns

4.1.2 Verification of Technical Analysis by Using Moving Average

In this part, the verification of technical analysis is based on the application of Moving Average, and according to the calculation results from the in-sample period, we choose the best combination of fast Moving Average (fast MA) and slow Moving Average (slow MA), and we apply this combination in the out-of-sample period to verify whether we make profit or not if we follow the signals it generates. Then we can make the conclusion whether the technical analysis works or not.

We set the feasible values for fast Moving Average to positive integers lower than 50, and for Slow Moving Average, we set the feasible values to positive integers lower than 250. Then we can generate 12,500 (12,500=50•250) combinations of fast Moving Average and slow Moving Average.

As we mentioned in chapter 3, based on the relationships between fast MA and slow MA, there are three possible positions in our trading system, they are long position (when we buy the asset) and short position (when we sell the asset), and moreover we should consider the neutral position (when we neither buy nor sell), and according to formula (3.11), we generate the corresponding values of different positions in Matlab. Then, we calculate the wealth evolution based on formula (3.13), and in the calculation, as we mentioned before, we make three assumptions of the transaction costs, the first one is set to 0.2%, the second one is set to 0.5% and the third one is set to 0%. At last, we calculate the final wealth which the investors would have possessed at the end of analyzed period (August 16th, 2010).

a) Transaction costs of 0.2%

We show the results of final wealth in Figure 4.2 (when transaction costs=0.2%). From Figure 4.2, we can see the values of final wealth are high in the periods of 40-50 days for fast MA and periods of 160-170 days for slow MA. The best combination is 46 days for fast MA and 163 days for slow MA, in this combination, the value of final wealth is 1.6735$.

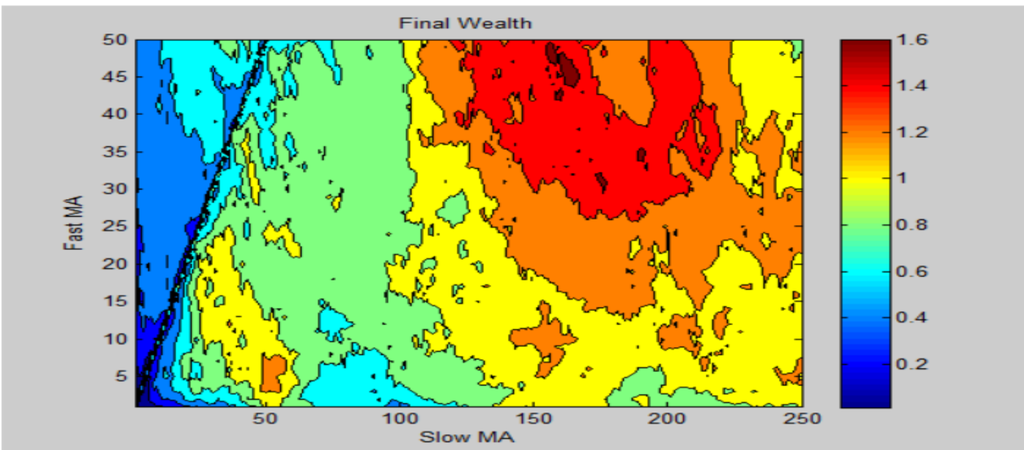

Figure 4.2 Final wealth in dependence on different combinations (transaction costs=0.2%)

Then we apply the best automated trading system (fast MA=46 days, slow MA=163 days) in the out-of-sample period. From the signals it generated, we can get the values of the positions, and in the same way and under the same conditions (we still set the initial value to 1$, and the transaction costs are set to 0.2% both for buying and selling orders), we calculate the wealth evolution during the out-of-sample period, we also show it in Figure 4.3.

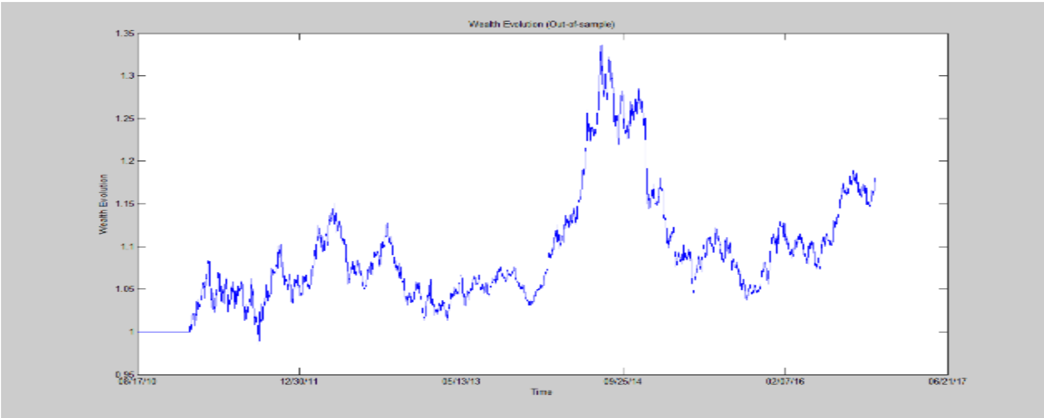

Figure 4.3 Wealth evolution (out-of-sample, transaction costs=0.2%)

On one hand, in Figure 4.3, during this period, we can see if we follow the signals which the combination of 46 days fast MA and 163 days slow MA generated, at the end of this period, the value of final wealth we would have possessed is 1.1807$, which is higher than the initial wealth value (that we have set it to 1$). On the other hand, we also calculate the average annual return based on the wealth evolution in the out-of-sample period, the calculation in Matlab is shown in Figure 4.4:

```
Samplesizeoos=2279;
AARoos=power(wealthoos(end),252/Samplesizeoos)-1
```

Figure 4.4 Calculations of average annual return

variables *samplesizeoos*, *AARoos* and *wealthoos* are the corresponding sample size, average annual returns and wealth evolution of the out-of-sample period, and from the calculations above, we know the average annual return in the out-of-sample period is a positive value which equals to 3.13%.

From all the results we get, we make the conclusion that we get profit based on the application of moving averages in our analysis, so the technical analysis works when we assume transaction costs to 0.2%.

b) Transaction costs of 0.5%

Keeping the other conditions constant, just changing the transaction costs from 0.2% to 0.5%, and executing the same steps as above, firstly, we can get the values of final wealth based on the in-sample data, we show this in Figure 4.5.

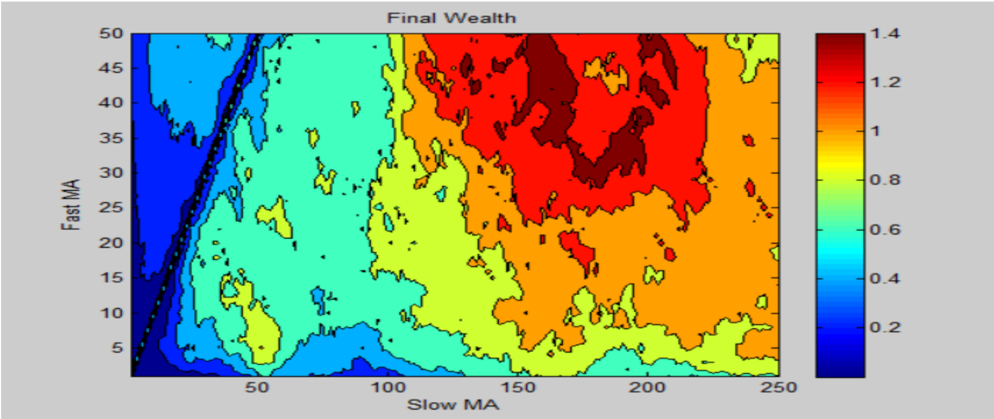

Figure 4.5 Final wealth in dependence on different combinations (transaction costs=0.5%)

The same as the situation when transaction costs are set to 0.2%, when we change the transaction costs to 0.5%, the best combination is also 46 days for fast MA and 163 days for slow MA, and in this combination, the value of final wealth is 1. 5805$.

We apply this combination in the out-of-sample period, and in Figure 4.6, we can see at the end of this period, the value of final wealth we would have possessed is 1.0951$, which is also higher than the initial wealth value (that we have set it to 1$). What's more, we also calculate the average annual return in the out-of-sample period, it is a positive value which equals to 1.01%.

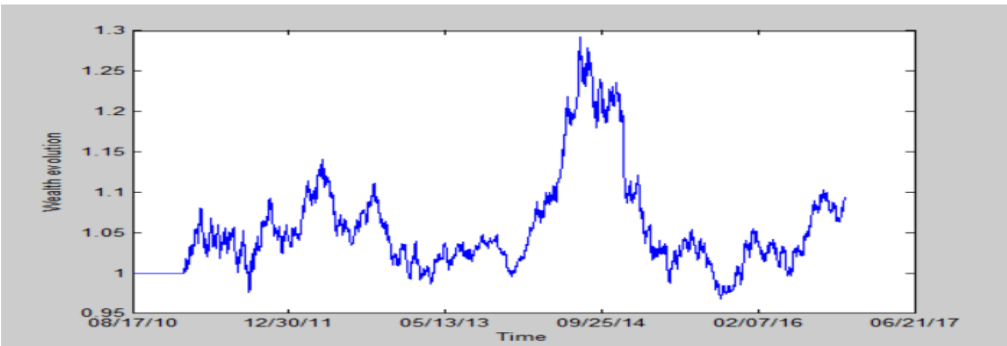

Figure 4.6 Wealth evolution (out-of-sample, transaction costs=0.5%)

From these results, we make the conclusion that technical analysis works based on the application of moving average in our analysis when we assume transaction costs to 0.5%.

c) Transaction costs of 0%

In this part, we set the transaction costs to 0%, which means there is no transaction costs incurred during the trading. Keeping the other conditions constant, executing the same steps, we can get the values of final wealth based on the in-sample data, we show this in Figure 4.7.

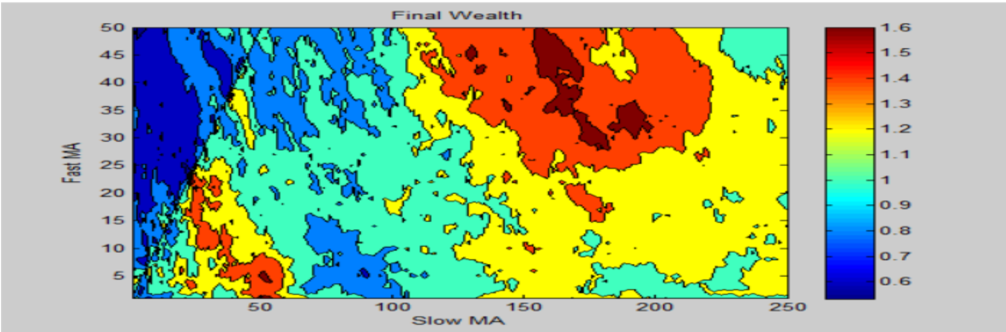

Figure 4.7 Final wealth in dependence on different combinations (transaction costs=0%)

From the results above, we know the best combination is 31 days for fast MA and 176 days for slow MA, and in this combination, the value of final wealth is 1.7536$.

We apply this combination in the out-of-sample period, and in Figure 4.8, we can see at the end of this period, the value of final wealth we would have possessed is 1.0849$, which is higher than the initial wealth value. We also calculate the average annual return in the out-of-sample period, it is a positive value which equals to 0.91%. From these results, we make the conclusion that technical analysis works based on the application of moving average in our analysis when we assume transaction costs to 0%.

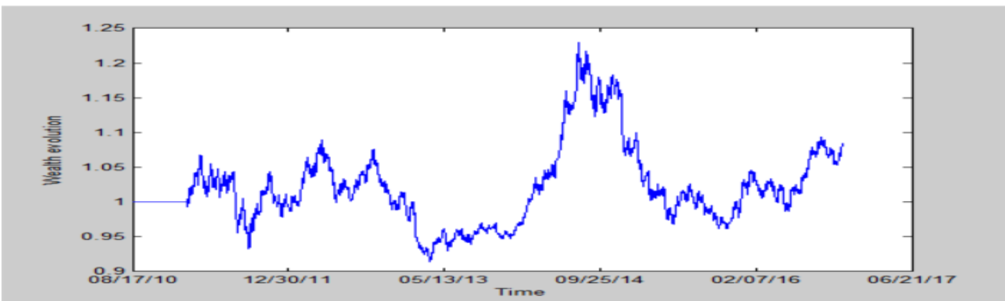

Figure 4.8 Wealth evolution (out-of-sample, transaction costs=0%)

4.1.3 Verification of Technical Analysis by Using Bollinger Bands

In this part, we apply the Bollinger Bands to make the verification. Similar to the steps in part 4.1.2, firstly, we set different values of periods for the moving average and different values of multiple of the standard deviation in the calculations, secondly, we calculate the wealth evolution and the final wealth under each combination of these two parameters, thirdly, we choose the combination which we can get the highest final wealth from. In the last step, we apply this combination in the out-of-sample period to verify whether we make profit or not if we follow the signals it generates. Then we can make the conclusion whether the technical analysis works or not.

We set the feasible values for Moving Average to positive integers from 1 to 250, and for the multiple of the standard deviation, we set its feasible values to 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5. According to the relationship between prices and Bollinger Bands, we can generate signals in our trading system, which we have described with details in formula (3.9) in chapter 3. Based on the signals generated, we can get the corresponding positions according to formula (3.11). Here we also make three assumptions of the transaction costs, they are set to 0.2%, 0.5% and 0%.

a) Transaction costs of 0.2%

We show the results of calculations of final wealth under different combinations in Figure 4.9, with the color of the points changing from blue to red as the values of the corresponding points become higher.

However, from Figure 4.9, we find under these combinations, the highest value of final wealth is 1$, which is equal to the initial wealth, it means there are no trading actions under that strategy, so, we cannot choose any profitable combination from the in-sample period. So, we make the conclusion that based on the application of Bollinger Bands in our analysis, the technical analysis doesn't work when we assume transaction costs to 0.2%.

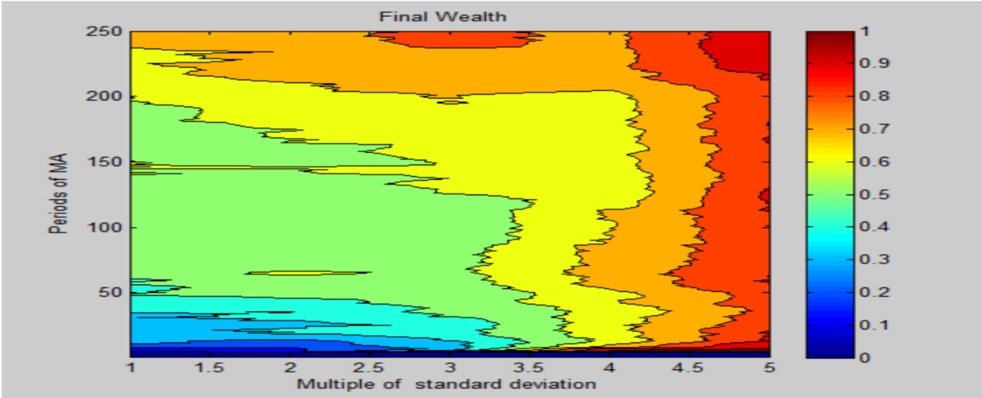

Figure 4.9 Final wealth in dependence on different combinations (transaction costs=0.2%)

b) Transaction costs of 0.5%

We change the transaction costs from 0.2% to 0.5% and keep the other conditions constant, then execute the same steps as above, we get the values of final wealth based on the in-sample data, we show this in Figure 4.10.

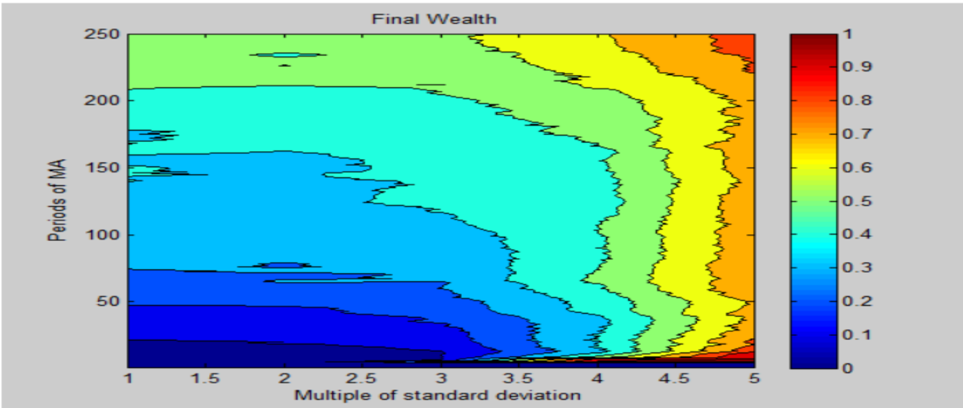

Figure 4.10 Final wealth in dependence on different combinations (transaction costs=0.5%)

In Figure 4.10, as the same as the situation in Figure 4.9, we find the highest value of final wealth is 1$, which means there is no strategy for investors to make profit in in-sample period. So, we make the conclusion that technical analysis doesn't work with the application of Bollinger Bands in our analysis when we assume transaction costs to 0.5%.

c) Transaction costs of 0%

We set transaction costs to 0% and keep the other conditions constant, then execute the same steps as above, we get the values of final wealth based on the in-sample data, we show this in Figure 4.11.

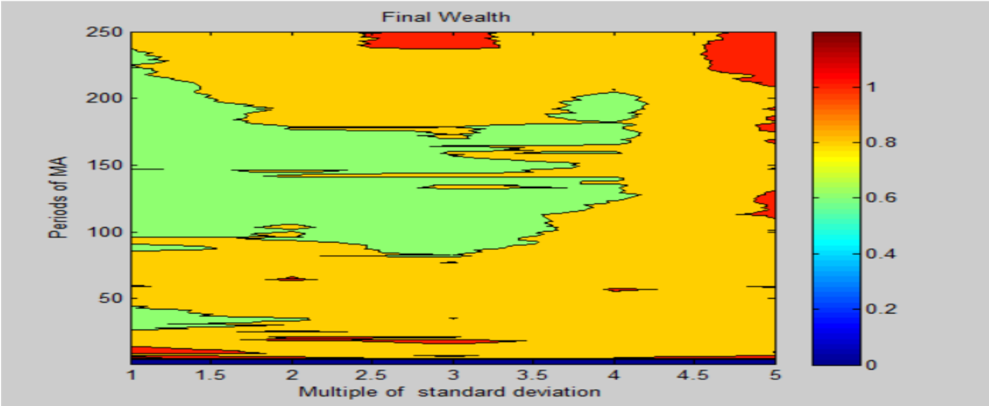

Figure 4.11 Final wealth in dependence on different combinations (transaction costs=0%)

In Figure 4.11, we find the highest value of final wealth is 1.2420$, and in the corresponding combination, the multiple of standard deviation is 1 and the periods of MA is 6 days. Then, we apply this strategy in the out-of-sample period, we can get the final wealth is equal to1.3318$ after that period, and the average annual return is 3.22%, we show this in Figure 4.12. So, we make the conclusion that technical analysis works with the application of Bollinger Bands in our analysis if there is no transaction costs incurred during the trading.

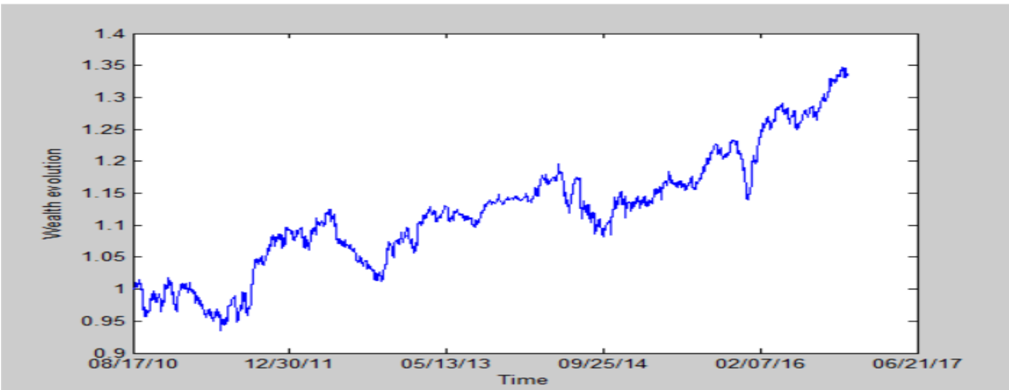

Figure 4.12 Wealth evolution (out-of-sample, transaction costs=0%)

4.1.4 Verification of Technical Analysis by Using RSI

Relative Strength Index (RSI) is applied to make the verification in this part. First of all, we set different values of periods for the calculation of RSI, then we calculate the wealth evolution and the final wealth under different periods, after that, we choose the best strategy in which we can get the highest final wealth. At last, we apply this strategy in the out-of-sample period to verify whether we make profit or not if we follow the signals it generates. Then we can conclude whether the technical analysis works or not from the results we get.

We set the feasible values of periods for the calculations of RSI to integers from 1 to 50. According to the relationship between RSI and its maximum limit (70) and minimum limit (30) which we have mentioned in chapter 3, we can generate signals in our trading system, we have described the rules with details in formula (3.10), then we can get the corresponding positions. We make three assumptions of the transaction costs, they are set to 0.2%, 0.5% and 0%.

a) Transaction costs of 0.2%

We show the values of final wealth in dependence on different periods of RSI in Figure 4.13, it's obvious that even the highest value of final wealth is lower than 1$, which is equal to 0.9575$ when the period of RSI is set to 36 days. It means if we choose any strategy from it, we make loss.

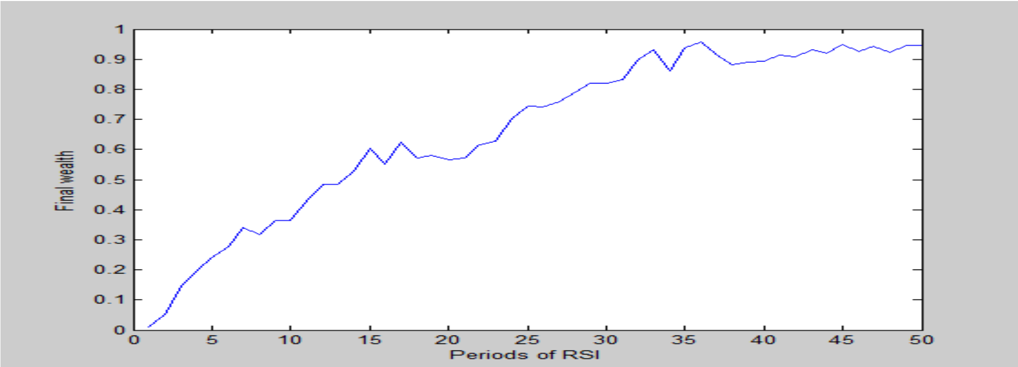

Figure 4.13 Final wealth of different periods of RSI (in-sample, transaction costs=0.2%)

According to the result we get above, we make the conclusion that technical analysis doesn't work based on the application of Relative Strength Index when we assume transaction costs to 0.2%.

b) Transaction costs of 0.5%

We change the transaction costs from 0.2% to 0.5%, then calculate the final wealth in dependence on different periods of RSI in in-sample period, and the result is shown in Figure 4.14. We can see the highest value of final wealth is still lower than 1$, which is equal to 0.8496$ when the period of RSI is set to 49 days. So, there is no strategy for investors to make profit in in-sample period. Based on this result, we make the conclusion that technical analysis doesn't work by the application of Relative Strength Index when we assume transaction costs to 0.5%.

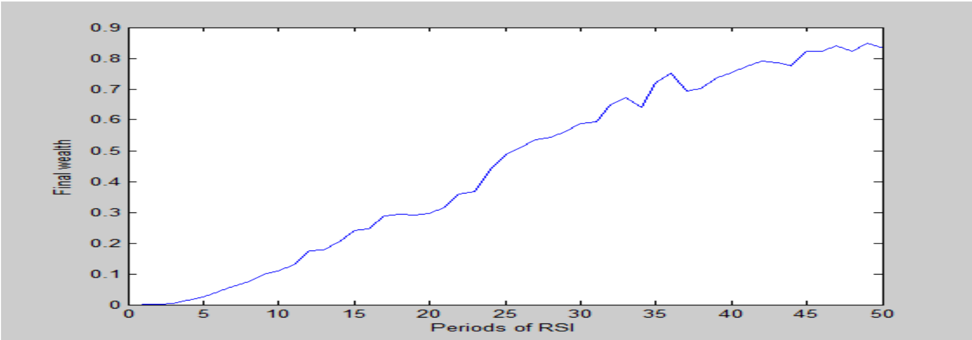

Figure 4.14 Final wealth of different periods of RSI (in-sample, transaction costs=0.5%)

c) Transaction costs of 0%

We set transaction costs to 0% and calculate the final wealth in dependence on different periods of RSI in in-sample period, and the results are shown in Figure 4.15. We can see the highest value of final wealth is equal to 1.4176$, and the corresponding period of RSI is 3 days.

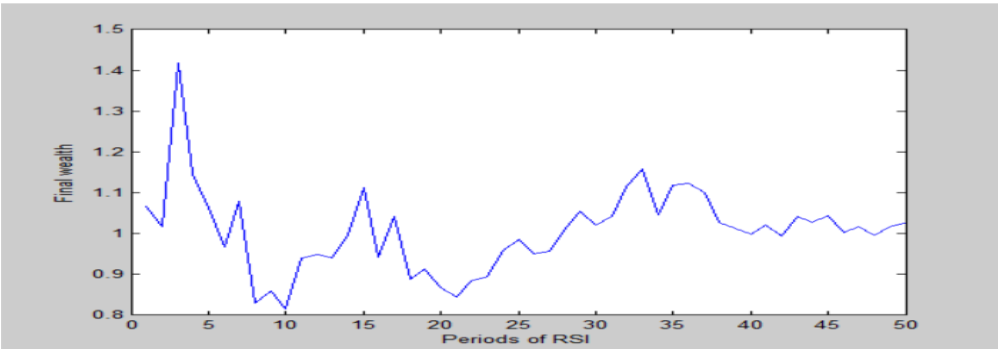

Figure 4.15 Final wealth of different periods of RSI (in-sample, transaction costs=0%)

We apply this strategy in the out-of-sample period, we show the result in Figure 4.16. We find that final wealth is equal to1.1976$ at the end of out-of-sample period, and the average annual return is a positive value which is equal to 2.01%. So, we can make the conclusion that technical analysis works by the application of Relative Strength Index when the transaction costs are set to 0%.

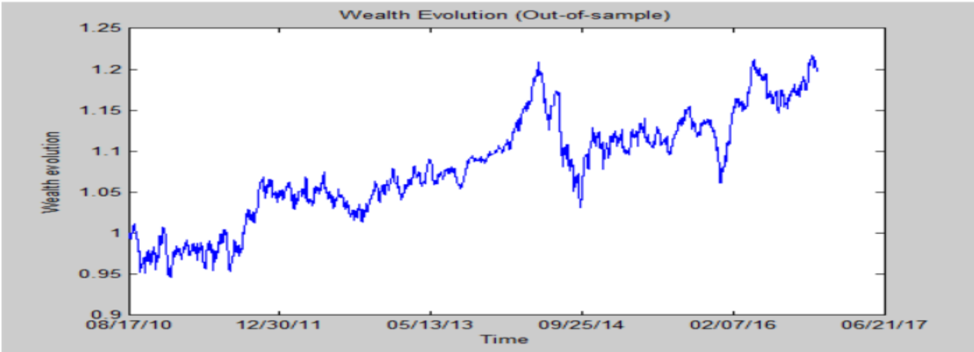

Figure 4.16 Wealth evolution (out-of-sample, transaction costs=0%)

4.2 Case 2-Stock BABA

In case 2, we make the verification of technical analysis based on the historical trading prices of Alibaba stock (BABA). Firstly, we describe the input data, then, we use the data to make some calculations, at last, we make conclusions from the calculations' results.

4.2.1 Input Data

First of all, we briefly describe the input data as well as Alibaba Group Holding Ltd. Secondly, we make the assumptions in our verification. Then, we show the development of the historical trading prices and calculate the returns of them, and the results of calculations are used in the later analysis.

a) Descriptions of the input data

The dataset we apply in the verification is the daily closing prices of the stock of the listed company- Alibaba Group Holding Ltd. Alibaba Group was founded in 1999 by Jack Ma, a former English teacher from Hangzhou, China. The founder started his company to champion small businesses, in the belief that the Internet would level the playing field by enabling small enterprises to leverage innovation and technology to grow and compete more effectively in the domestic and global economies. Through its subsidiaries, the company is principally engaged in online and mobile commerce through offering of products, services and technology that enable merchants, brands and other businesses to transform the way they market. The Company's businesses consist of core commerce, cloud computing, mobile media and entertainment, and other innovation initiatives. In September 19th, 2014, Alibaba Group was formally listed on the New York stock exchange, with the stock code "BABA",

b) Assumptions in the verification

In our verification, the same as Case 1, we assume that initial wealth w_0 is equal to 1$, and we make three assumptions of the *transaction costs* here, the first one is set to 0.2%, the second one is set to 0.5%, and the third one is set to 0%, that transaction costs are equal to 0% means there is no transaction costs incurred during the trading.

c) Input data and calculations of returns

We also download the data from the website www.investing.com. The period of applied data is selected from September 22th, 2014 to March 1st, 2018. The whole sample size is 867. We divide the data into two parts, they are in-sample period and out-of-sample period. In in-sample period, the duration of data is from September 22th, 2014 to June 10th, 2016, and in out-of-sample period, the duration of data is from June 13th, 2016 to March 1st, 2018. Each part approximately accounts for 50% of the whole period. We show the data of each part as well as the calculations of returns of them in Figure 4.17.

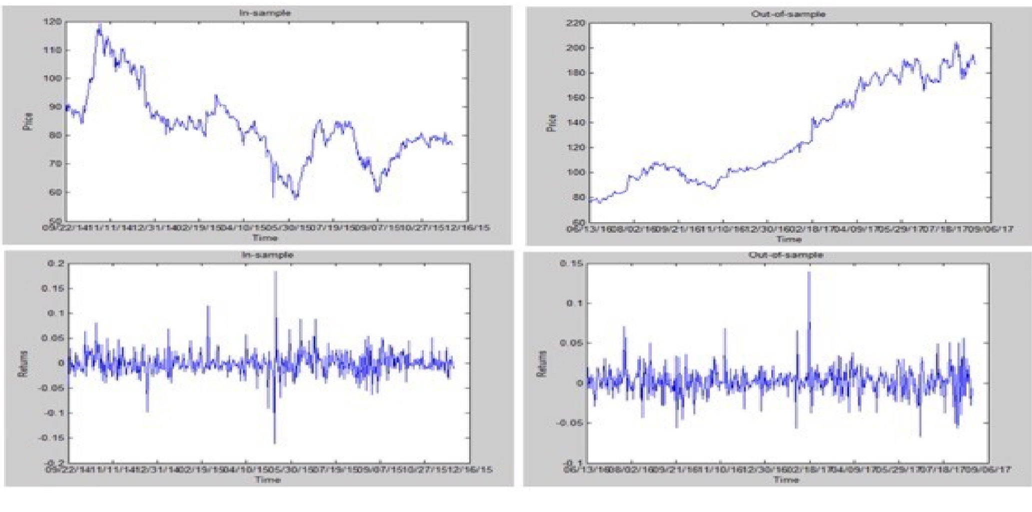

Figure 4.17 Closing prices of stock BABA and the returns

4.2.2 Verification of Technical Analysis by Using Moving Average

In this part, we verify the technical analysis by using Moving Average, and according to the calculation results from the in-sample period, we choose the best combination of fast Moving Average (fast MA) and slow Moving Average (slow MA), and we apply this combination in the out-of-sample period to verify whether we make profit or not if we follow the signals it generates. Then we can make the conclusion whether the technical analysis works or not.

Comparing with Case 1, the sample size is smaller in Case 2, so, we set the feasible values for fast Moving Average to positive integers lower than 30, and for Slow Moving Average, we set the feasible values to positive integers lower than 150. Then we can generate 4,500 (4,500=30x150) combinations of fast Moving Average and slow Moving Average.

a) Transaction costs of 0.2%

We show the results of final wealth in Figure 4.18 (when transaction costs=0.2%). From Figure 4.18, we can see the best combination is 20 days for fast MA and 24 days for slow MA, in this combination, the value of final wealth is 1.5375$.

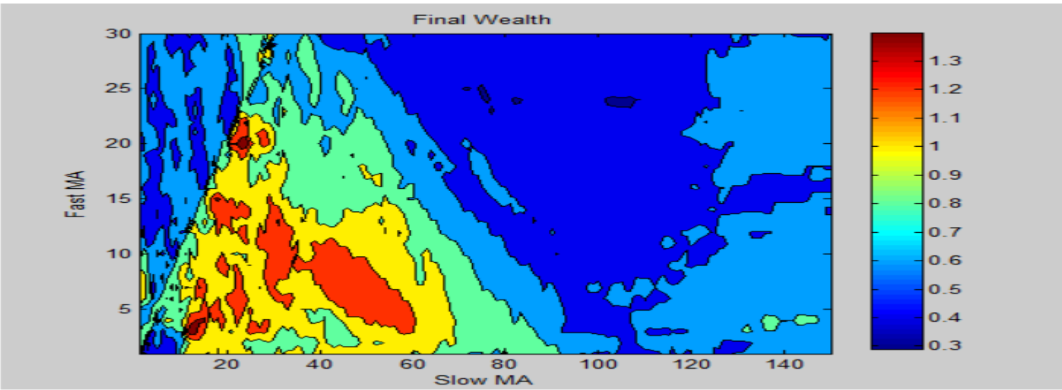

Figure 4.18 Final wealth in dependence on different combinations (transaction costs=0.2%)

Then we apply the best automated trading system (fast MA=20 days, slow MA=24 days) in the out-of-sample period. In the same way and under the same conditions (we still set the initial value to 1$, and the transaction costs are set to 0.2% both for buying and selling orders), we calculate the wealth evolution during the out-of-sample period, we show the result in Figure 4.19.

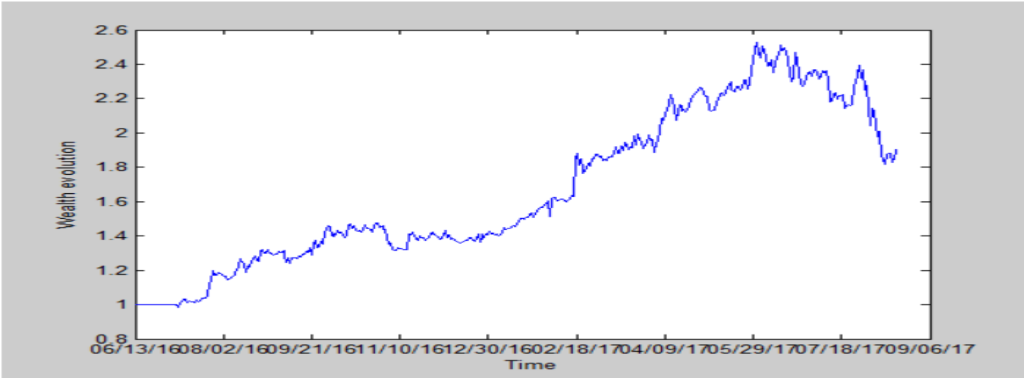

Figure 4.19 Wealth evolution (out-of-sample, transaction costs=0.2%)

From Figure 4.19, we can see at the end of this period, the value of final wealth we would have possessed is 1.9094$, which is higher than the initial wealth value which we have set it to 1$. We also calculate the average annual return based on the wealth evolution in the out-of-sample period, and the value of average annual return in the out-of-sample period is a positive value which equals to 45.71%.

So, we make the conclusion that we get profit based on the application of moving average in our analysis, so the technical analysis works efficiently when the transaction costs are set to 0.2%.

b) Transaction costs of 0.5%

Keeping the other conditions constant, change the transaction costs from 0.2% to 0.5%, and executing the same steps as above, we can get the values of final wealth based on the in-sample data, we show this in Figure 4.20.

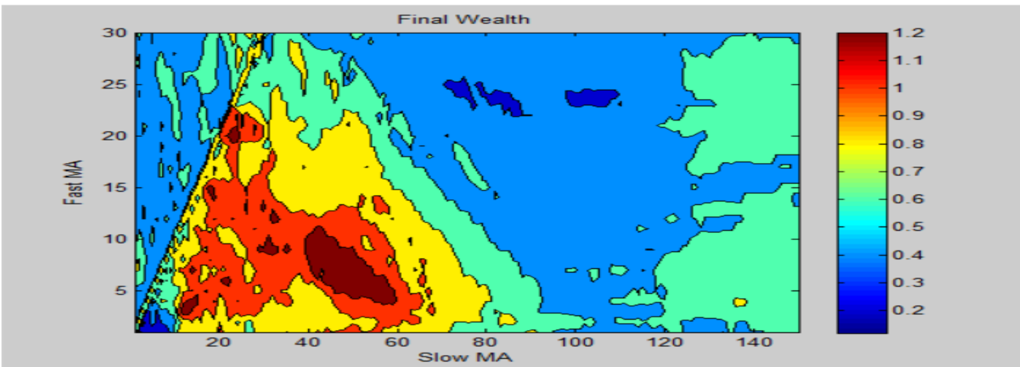

Figure 4.20 Final wealth in dependence on different combinations (transaction costs=0.5%)

From Figure 4.20, we know the best combination is also 20 days for fast MA and 24 days for slow MA, and in this combination, the value of final wealth is 1. 3921$. We apply this combination in the out-of-sample period, and in Figure 4.21, we can see at the end of this period, the value of final wealth we would have possessed is 1.6775$, which is also higher than the initial wealth value. And we calculate the average annual return in the out-of-sample period, it is a positive value which equals to 35.13%. So, we make the conclusion that technical analysis works efficiently based on the application of moving average in our analysis when the transaction costs are set to 0.5%.

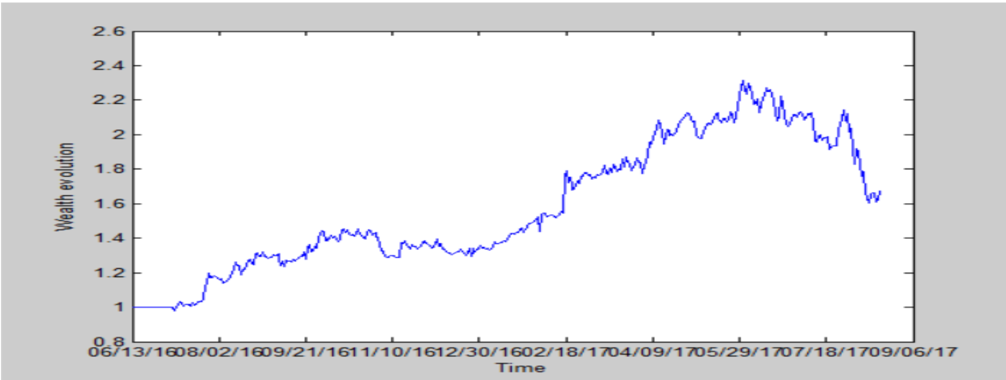

Figure 4.21 Wealth evolution (out-of-sample, transaction costs=0.5%)

c) Transaction costs of 0%

In this part, we set the transaction costs to 0%, which means there is no transaction costs incurred during the trading. Keeping the other conditions constant, executing the same steps, we can get the values of final wealth based on the in-sample data, we show this in Figure 4.22.

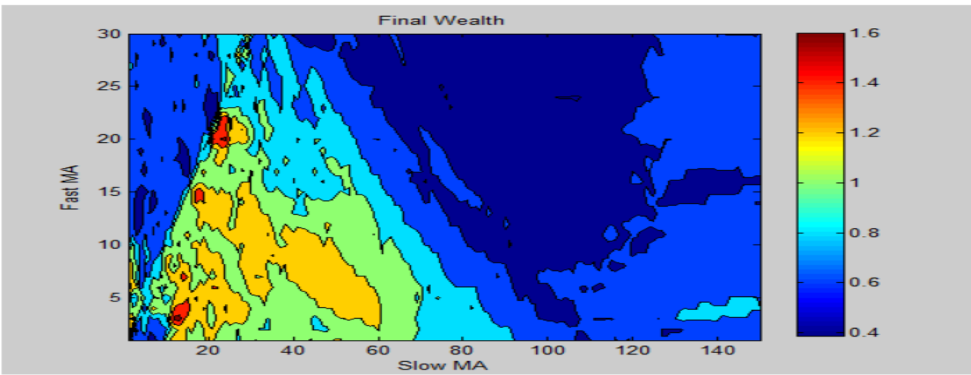

Figure 4.22 Final wealth in dependence on different combinations (transaction costs=0%)

From the results above, we know the best combination is 3 days for fast MA and

13 days for slow MA, and in this combination, the value of final wealth is 1.6717$. We apply this combination in the out-of-sample period, and in Figure 4.23, we can see at the end of this period, the value of final wealth we would have possessed is 1.1459$, which is higher than the initial wealth value. We also calculate the average annual return in the out-of-sample period, it is a positive value which equals to 8.25%. From these results, we make the conclusion that when the transaction costs are set to 0%, technical analysis works by the application of moving average in our analysis.

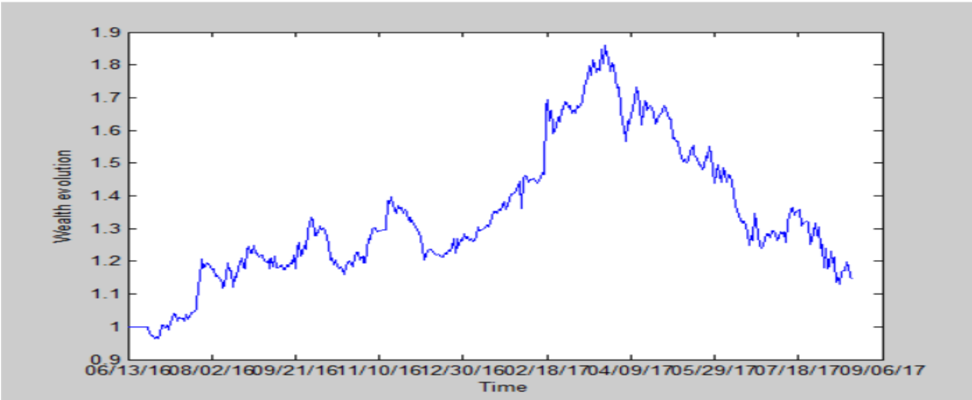

Figure 4.23 Wealth evolution (out-of-sample, transaction costs=0%)

4.2.3 Verification of Technical Analysis by Using Bollinger Bands

In this part, we apply the Bollinger Bands to make the verification. Firstly, we set different values of periods for the moving average and different values of multiple of the standard deviation in the calculations, secondly, we calculate the wealth evolution and the final wealth under each combination of these two parameters, thirdly, we choose the combination which we can get the highest final wealth from. In the last step, we apply this combination in the out-of-sample period to verify whether we make profit or not if we follow the signals it generates. Then we can make the conclusion whether the technical analysis works or not.

We set the feasible values for Moving Average to positive integers from 1 to 150, and for the multiple of the standard deviation, we set its feasible values to 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5. Here we also make three assumptions of the transaction costs, they are set to 0.2%, 0.5% and 0%.

a) Transaction costs of 0.2%

We show the results of calculations of final wealth under different combinations in Figure 4.24. From Figure 4.24, we find the highest value of final wealth is 1.5217$, and in the corresponding combination, the multiple of the standard deviation is 4 and the periods of MA is 12 days.

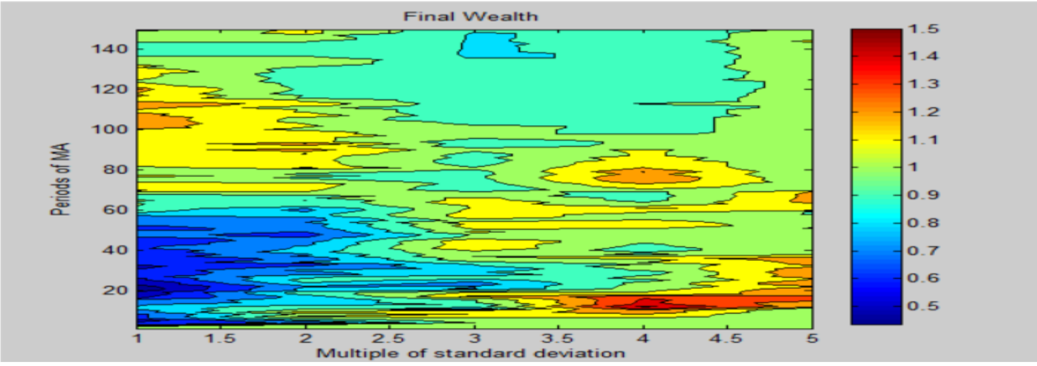

Figure 4.24 Final wealth in dependence on different combinations (transaction costs=0.2%)

We apply this combination in the out-of-sample period, and in Figure 4.25, we can see during the whole period, the value of wealth we would have possessed is always 1$, which means there is no trading action when we apply this combination in the out-of-sample period. That's because the duration of out-of-sample period is quite short.

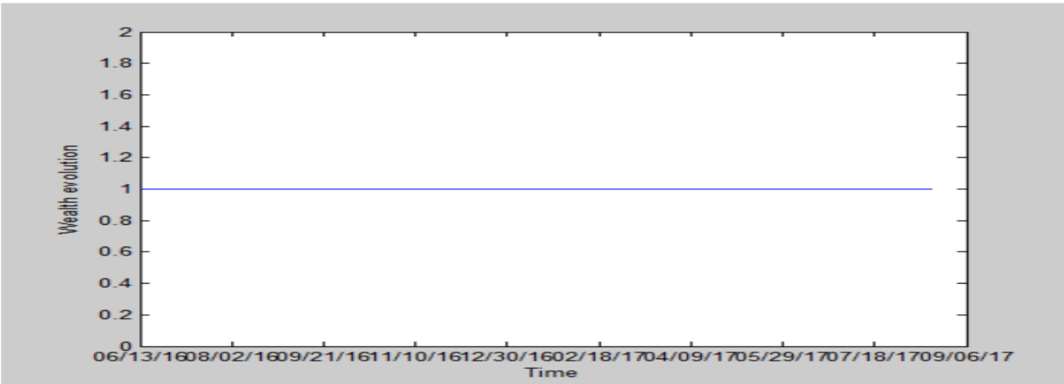

Figure 4.25 Wealth evolution (out-of-sample, transaction costs=0.2%)

b) Transaction costs of 0.5%

We change transaction costs from 0.2% to 0.5% and keep the other conditions constant, then execute the same steps as above, we get the values of final wealth based on the in-sample data, we show this in Figure 4.26.

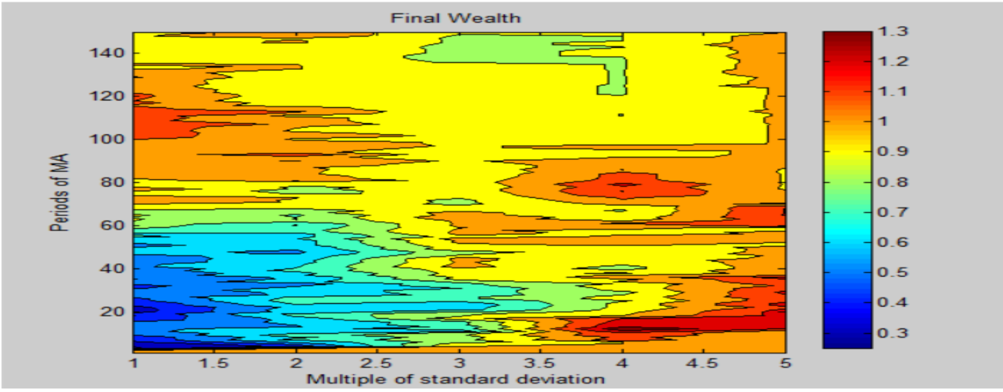

Figure 4.26 Final wealth in dependence on different combinations (transaction costs=0.5%)

In Figure 4.26, as the same as the situation in Figure 4.24, we find in the best strategy here, the multiple of the standard deviation is 4 and the periods of MA is 12 days, and its correspond highest final wealth is 1.3736$. And we apply this combination in the out-of-sample period, but the same as the situation in Figure 4.25, during the whole period, the value of wealth we would have possessed is always 1$. That's because the duration of out-of-sample period is quite short.

c) Transaction costs of 0%

We set transaction costs to 0% and keep the other conditions constant, then execute the same steps as above, we get the values of final wealth based on the in-sample data, we show this in Figure 4.27.

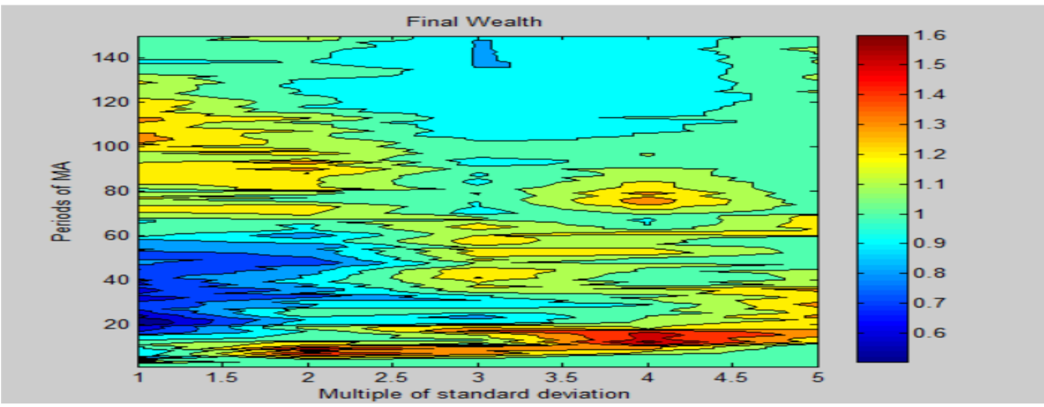

Figure 4.27 Final wealth in dependence on different combinations (transaction costs=0%)

In Figure 4.27, we find the highest value of final wealth is 1.6289$, and in the corresponding combination, the multiple of standard deviation is 4 and the periods of

MA is 12 days. However, after we apply this combination in the out-of-sample period, we find the same as the situations when we set the transaction costs to 0.2% and 0.5%, during the whole period, the value of wealth we would have possessed is always 1$. The same as before, that's because the duration of out-of-sample period is quite short.

4.2.4 Verification of Technical Analysis by Using RSI

Relative Strength Index (RSI) is applied to make the verification in this part. Firstly, we set different values of periods for the calculation of RSI, then we calculate the wealth evolution and the final wealth under different periods, after that, we choose the best strategy in which we can get the highest final wealth. At last, we apply this strategy in the out-of-sample period to verify whether we make profit or not if we follow the signals it generates. Then we can conclude whether the technical analysis works or not from the results we get.

We set the feasible values of periods for the calculations of RSI to integers from 1 to 50, we make three assumptions of the transaction costs, they are set to 0.2%, 0.5% and 0%.

a) Transaction costs of 0.2%

We show the values of final wealth in dependence on different periods of RSI in Figure 4.28, we can see the highest value of final wealth is 1.3805$, and the corresponding period of RSI is 32 days.

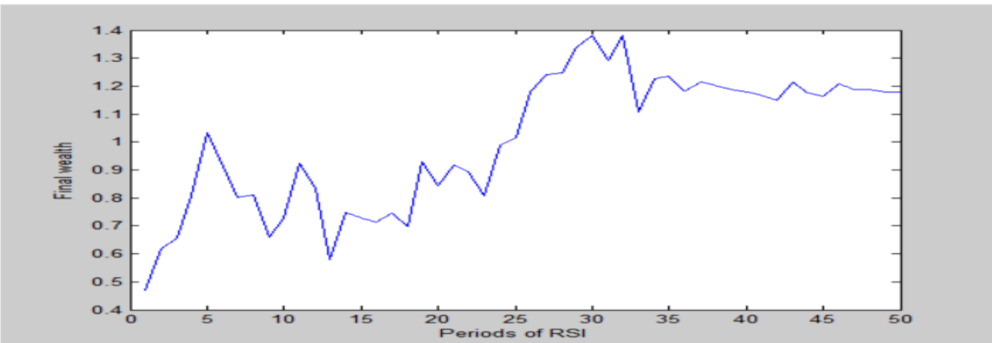

Figure 4.28 Final wealth of different periods of RSI (in-sample, transaction costs=0.2%)

We apply this strategy in the out-of-sample period, we show the result in Figure 4.29. We find that final wealth is equal to 1.003$ at the end of out-of-sample period, and the average annual return is a positive value which is equal to 0.18%. So, we can make the conclusion that technical analysis works by the application of Relative Strength Index when we set the transaction costs to 0.2%.

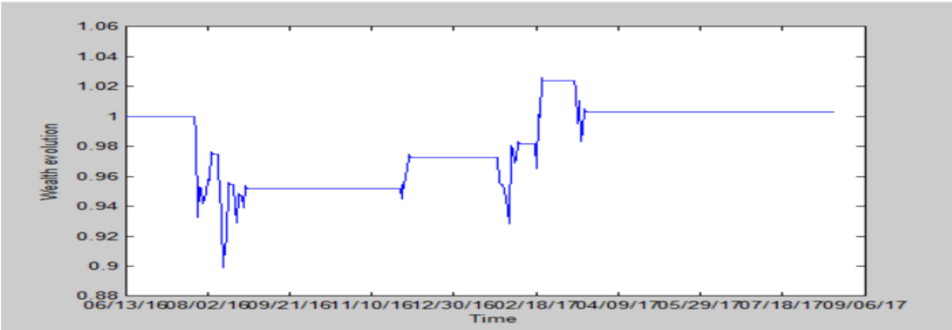

Figure 4.29 Wealth evolution (out-of-sample, transaction costs=0.2%)

b) Transaction costs of 0.5%

We change the transaction costs from 0.2% to 0.5%, then calculate the final wealth in dependence on different periods of RSI in in-sample period, and the result is shown in Figure 4.30. We can see the highest value of final wealth is equal to 1.3077$ when the period of RSI is 32 days.

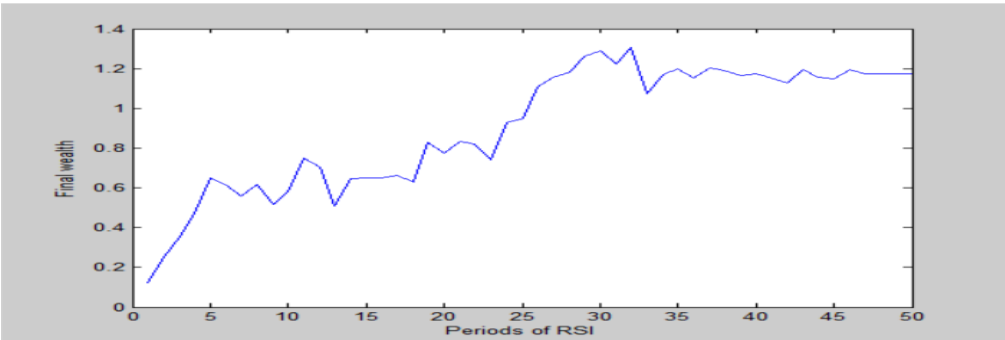

Figure 4.30 Final wealth of different periods of RSI (in-sample, transaction costs=0.5%)

We apply this strategy in the out-of-sample period, the result is shown in Figure 4.31. We find that final wealth is equal to 0.9387$ at the end of out-of-sample period, and the average annual return is a negative value which is equal to -3.61%. So, we can make the conclusion that technical analysis doesn't work by the application of Relative Strength Index when we set the transaction costs to 0.5%.

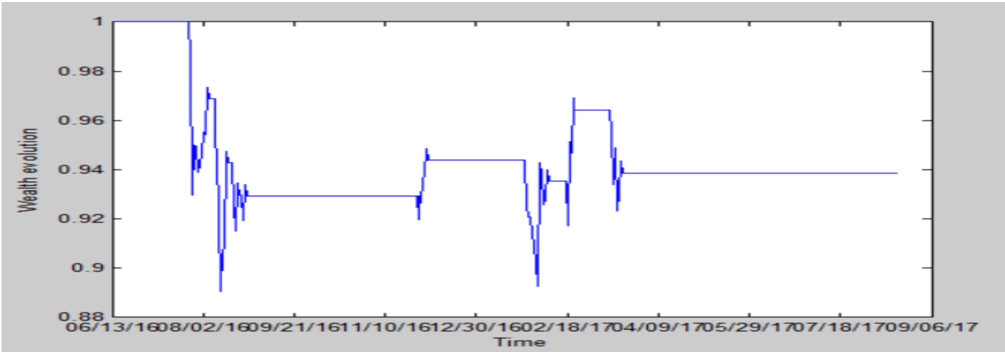

Figure 4.31 Wealth evolution (out-of-sample, transaction costs=0.5%)

c) Transaction costs of 0%

We set transaction costs to 0% and calculate the final wealth in dependence on different periods of RSI in in-sample period, and the result is shown in Figure 4.32. We can see the highest value of final wealth is equal to 1.4417$, and the corresponding period of RSI is 30 days.

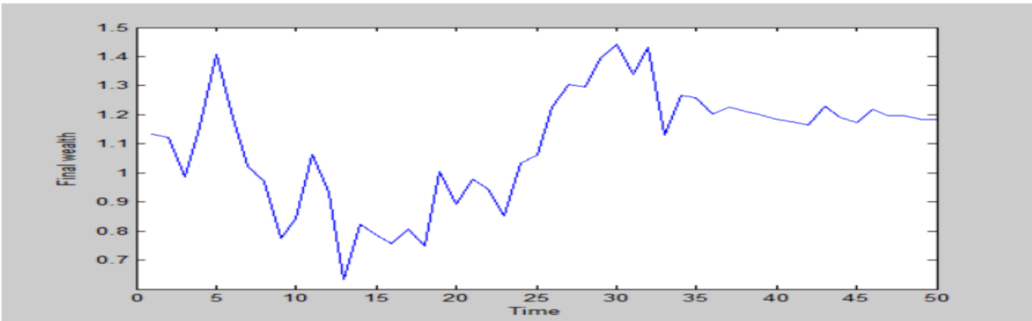

Figure 4.32 Final wealth of different periods of RSI (in-sample, transaction costs=0%)

We apply this strategy in the out-of-sample period, we show the result in Figure 4.33. We find that final wealth is equal to 1.0325$, and the average annual return is a positive value which is equal to 1.88%. So, we can make the conclusion that technical analysis works by the application of Relative Strength Index when we set the transaction costs to 0%.

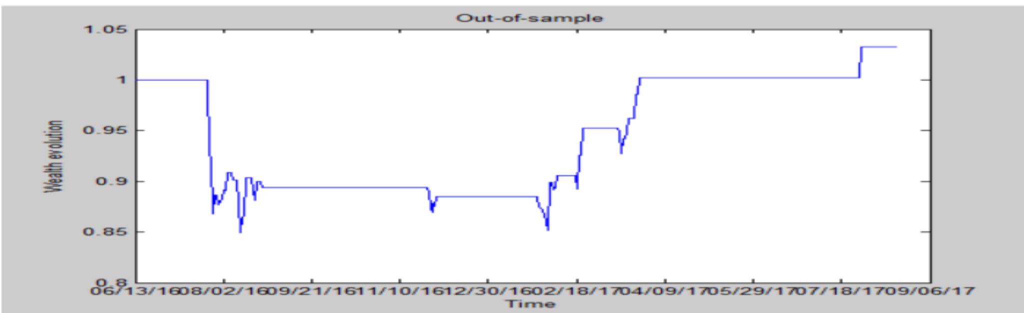

Figure 4.33Wealth evolution (out-of-sample, transaction costs=0%)

4.3 Summary of Case 1 and Case 2

In this part, in Table 4.2, we summarize the results which we get from the analysis in the two cases.

Table 4.2 Summary of results from Case 1 and Case 2

Case 1	**MA**		**BB**		**RSI**	
TC	**In**	**Out**	**In**	**Out**	**In**	**Out**
0.2%	fMA=46, sMA=163		-		-	
	F=1.6735 R=5.86%	F=1.1807 R=3.13%	F=1 R=0%	-	Loss	-
0.5%	fMA=46, sMA=163		-		-	
	F=1.5805 R=5.19%	F=1.0951 R=1.01%	F=1 R=0%	-	Loss	-
0%	fMA=31, sMA=176		MA=6, m.std=1		P=3	
	F=1.7536 R=6.40%	F=1.0849 R=0.91%	F=1.2420 R=2.42%	F=1.3318 R=3.22%	F=1.4176 R=3.93%	F=1.1976 R=2.01%
Case 2	**MA**		**BB**		**RSI**	
TC	**In**	**Out**	**In**	**Out**	**In**	**Out**
0.2%	fMA=20, sMA=24		MA=12, m.std=4		P=32	
	F=1.5375 R=28.37%	F=1.9094 R=45.71%	F=1.5217 R=27.61%	F=1 R=0%	F=1.3805 R=20.59%	F=1.003 R=0.18%
0.5%	fMA=20, sMA=24		MA=12, m.std=4		P=32	
	F=1.3921 R=21.18%	F=1.6775 R=35.13%	F=1.3736 R=20.24%	F=1 R=0%	F=1.3077 R=16.86%	Loss
0%	fMA=3, sMA=13		MA=12, m.std=4		P=30	
	F=1.6717 R=34.76%	F=1.1459 R=8.25%	F=1.6289 R=32.75%	F=1 R=0%	F=1.4417 R=23.67%	F=1.0325 R=1.88%

In Table 4.2, *TC* is transaction cost, *MA* is the moving average, *BB* is the Bollinger Bands, *RSI* is the relative strength index, *m.std* is the multiple of standard deviation, *P* is the periods of RSI, *F* is the final wealth and *R* is the average annual return. What's more, *In* means the in-sample period and *Out* means the out-of-sample period.

From Table 4.2, we find that moving average works well in the verification of technical analysis in both cases, based on it, if we apply the best strategies in the out-of-sample period, we can get profits. In Case 1, in the use of Bollinger bands, only if we set the transaction costs to zero, we can find the best strategy and apply it in the out-of-sample period to make profit, however, it's impossible to pay no fees during any transaction, so, Bollinger bands doesn't work in Case 1. In Case 2, we can find best strategies in the in-sample period by using Bollinger bands, however, because the duration of out-of-sample period is too short in Case 2, the best strategies cannot make any profit when we apply them in the out-of-sample period as the result of no trading. As for the relative strength index, it doesn't work unless there are no transaction costs in Case 1, but it works in Case 2 when the transaction costs is set to 0.2% or zero.

5. Conclusion

Technical analysis is an analytical method to forecast the future directions of prices movements based on a security's past trading data, primarily prices and trading volumes or index values. Technical analysis study the action of the market itself, which disregards all other psychological factors or the intrinsic value of the stock.

The goal of this thesis is to verify technical analysis based on the historical trading data of EUR/USD currency pair and the historical trading data of the stock of Alibaba Group Holding Ltd.

We make analysis of two cases in this thesis. In Case 1, the dataset is the historical daily closing prices of EUR/USD currency pair from May 5th, 2003 to November 27th, 2017. In Case 2, the dataset is the historical daily closing prices of the stock of Alibaba Group Holding Ltd from September 22th, 2014 to March 1st, 2018.

In this thesis, we make the verification of technical analysis based on three types of indicators, they are Moving Average (MA), Bollinger Bands and Relative Strength Index (RSI). We make descriptions of them in chapter 3, and apply them in the cases in chapter 4.

Both in Case 1 and Case 2, when we use the moving average in our analysis, we find that if we apply the best strategy in the out-of-sample period, we make profit, which means the technical analysis works. And the changes of values of transaction costs doesn't have any influence on this conclusion.

However, in the application of Bollinger Bands in Case 1, we find we cannot choose any profitable strategy from the in-sample part unless we set the transaction costs to zero. And in Case 2, when we use the Bollinger Bands in our analysis, no matter what the value of transaction costs is, after we apply the best strategy which we get from the in-sample part, we can't make any profit in the out-of-sample part, because there are no trading signals generated when we apply the best strategies, that might be the result of the short duration of the out-of-sample period.

In Case 1, when we use the relative strength index in our analysis, we find when we set the transaction costs to 0.2% or 0.5%, there is no profitable strategy in the in-sample period, and the technical analysis only works by using the relative strength index when we set the transaction costs to zero. In Case 2, in the applications of relative strength index, we find the technical analysis works when we set the transaction costs to 0.2% or to zero, but when we set the transaction costs to 0.5%, the application of the best strategy which we get from the analysis in the in-sample part lead to a loss in the out-of-sample part.

So, we make a conclusion that technical analysis works when we apply the moving averages in our analysis. As for the Bollinger Bands, it doesn't help investors a lot to make any profit in our two cases, which means technical analysis doesn't work well when we use this type of indicator in our analysis. And in the applications of relative strength index, we find the value of transaction costs has a nonnegligible influence on the verification of technical analysis.

In a word, technical analysis helps a lot if we choose the suitable tools like technical indicators during the trading. However, if we wish to increase the possibility to make profit, we should also consider the fundamental analysis and psychological analysis, the combination of these three analytical methods can help investors to make profitable decisions in their financial activities.

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List of Abbreviations

MA - Moving Average

SMA - Simple Moving Average

EMA - Exponential Moving Average

MACD - Moving Average Convergence Divergence

RSI - Relative Strength Index

BB - Bollinger Bands

AG - Average gain

AL - Average loss

σ - Standard deviation

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List of Annexes

Annex A **Matlab Programs-Case 1-EUR/USD Currency Pair**

Annex B **Matlab Programs-Case 2- Stock BABA**

Annex A Matlab Programs-Case 1-EUR/USD Currency Pair

Program A1 Moving average

```
clear; clc;
importdata('Insample.xlsx');
price=ans.data;
clear ans;
importdata('Outofsample.xlsx');
priceoos=ans.data;
clear ans;
fee=0.002
returns=price(2:end)./price(1:end-1)-1;
returnsoos=priceoos(2:end)./priceoos(1:end-1)-1;
% In-sample
begining=251;
for a=1:50
    for b=1:250
        MAfast=tsmovavg(price,'s',a,1);
        MAslow=tsmovavg(price,'s',b,1);
        difference=MAfast-MAslow;
        difference(1:begining-1)=0;
        position=zeros(50,250,size(price,1));
        for i=1:length(difference)
            if difference(i)>0
                position(a,b,i)=1;
            elseif difference(i)<0
                position(a,b,i)=-1;
            else
                position(a,b,i)=0;
            end
```

```
            end
            fees=[1; power(1-fee,abs(diff(squeeze(position(a,b,1:end-1)))))];
            wealth(a,b,:)=cumprod((1+returns.*squeeze(position(a,b,1:end-1))).*fees);
        end
end
finalwealth=squeeze(wealth(:,:,end));
maxFW=max(max(finalwealth))
figure; contourf(finalwealth);
% Out-of-sample
fastMA31=tsmovavg(priceoos,'s',31,1);
slowMA176=tsmovavg(priceoos,'s',176,1);
differenceoos=fastMA31-slowMA176;
differenceoos(1:176-1)=0;
positionoos=zeros(size(priceoos));
for m=1:length(differenceoos)
    if differenceoos(m)>0
        positionoos(m)=1;
    elseif differenceoos(m)<0
        positionoos(m)=-1;
    else
        positionoos(m)=0;
    end
end
feesoos=[1; power(1-fee,abs(diff(positionoos(1:end-1))))];
wealthoos=cumprod((1+returnsoos.*positionoos(1:end-1)).*feesoos);
figure; plot(wealthoos); dateaxis('x',2,'08/17/10')
finalwealthoos=wealthoos(end)
Samplesizeoos=2279;
AARoos=power(wealthoos(end),252/Samplesizeoos)-1
```

Program A2 Bollinger bands

```
clear; clc;
importdata('Insample.xlsx');
price=ans.data;
clear ans;
importdata('Outofsample.xlsx');
priceoos=ans.data;
clear ans;
fee=0.002
returns=price(2:end)./price(1:end-1)-1;
returnsoos=priceoos(2:end)./priceoos(1:end-1)-1;
for a=5:250
    for b=1:0.5:3
        [mid, uppr, lowr]=bollinger(price,a,1,b);
        positions=zeros(size(price));
        for c=1:length(price)
            if price(c)>uppr(c)
                positions(c)=-1;
            elseif price(c)<lowr(c)
                positions(c)=1;
            else
                positions(c)=0;
            end
        end
        position(a,2*b-1,:)=positions;
        fees=[1; power(1-fee,abs(diff(squeeze(position(a,2*b-1,1:end-1)))))];
        wealth(a,2*b-1,:)=cumprod((1+returns.*squeeze(position(a,2*b-1,1:end-
1))).*fees);
    end
```

```
    disp(a)
end
finalwealth=squeeze(wealth(:,:,end));
maxFW=max(max(finalwealth))
figure; contourf(finalwealth);
%the following is when a=5,b=4
[midoos, upproos, lowroos]=bollinger(priceoos,5,1,4);
        positionsoos=zeros(size(priceoos));
        for d=1:length(priceoos)
            if priceoos(d)>upproos(d)
                positionsoos(d)=-1;
            elseif priceoos(d)<lowroos(d)
                positionsoos(d)=1;
            else
                positionsoos(d)=0;
            end
        end
feesoos=[1; power(1-fee,abs(diff(squeeze(positionsoos(1:end-1)))))];
wealthoos=cumprod((1+returnsoos.*squeeze(positionsoos(1:end-1))).*feesoos);
        finalwealthoos=wealthoos(end)
Samplesizeoos=2279;
AARoos=power(wealthoos(end),252/ Samplesizeoos)-1
```

Program A3 Relative strength index

```
clear; clc;
importdata('Insample.xlsx');
price=ans.data;
clear ans;
importdata('Outofsample.xlsx');
priceoos=ans.data;
clear ans;
fee=0.002;
returns=price(2:end)./price(1:end-1)-1;
returnsoos=priceoos(2:end)./priceoos(1:end-1)-1;
for a=1:50
    rsi=rsindex(price,a);
    positions=zeros(size(price));
    for i=1:length(rsi)
        if rsi(i)<30
            positions(i)=1;
        elseif rsi(i)>70
            positions(i)=-1;
        else
            positions(i)=0;
        end
    end
    fees=[1; power(1-fee,abs(diff(positions(1:end-1))))];
    wealth(a,:)=cumprod((1+returns.*positions(1:end-1)).*fees);
    disp(a)
end
finalwealth=squeeze(wealth(:,end)); maxFW=max(max(finalwealth))
figure; plot(1:50,finalwealth);
```

Annex B Matlab Programs-Case 2- Stock BABA

Program A4 Moving average

```
clear; clc;
importdata('In.xlsx');
price=ans.data;
clear ans;
importdata('Out.xlsx');
priceoos=ans.data;
clear ans;
fee=0.002
returns=price(2:end)./price(1:end-1)-1;
returnsoos=priceoos(2:end)./priceoos(1:end-1)-1;
figure; plot(returns); dateaxis('x',2,'09/22/14')
figure; plot(returnsoos); dateaxis('x',2,'06/13/16')
figure; plot(price); dateaxis('x',2,'09/22/14')
figure; plot(priceoos); dateaxis('x',2,'06/13/16')
% In-sample
begining=151;
for a=1:30
    for b=1:150
        fastMA=tsmovavg(price,'s',a,1);
        slowMA=tsmovavg(price,'s',b,1);
        difference=fastMA-slowMA;
        difference(1:begining-1)=0;
        position=zeros(30,150,size(price,1));
        for i=1:length(difference)
            if difference(i)>0
                position(a,b,i)=1;
            elseif difference(i)<0
                position(a,b,i)=-1;
```

```
            else
                position(a,b,i)=0;
            end
        end
        fees=[1; power(1-fee,abs(diff(squeeze(position(a,b,1:end-1)))))];
        wealth(a,b,:)=cumprod((1+returns.*squeeze(position(a,b,1:end-1))).*fees);
    end
end
finalwealth=squeeze(wealth(:,:,end)); maxFW=max(max(finalwealth))
figure; contourf(finalwealth);
% Out-of-sample
fastMA20=tsmovavg(priceoos,'s',20,1); slowMA24=tsmovavg(priceoos,'s',24,1);
differenceoos=fastMA20-slowMA24;
differenceoos(1:24-1)=0;
positionoos=zeros(size(priceoos));
for m=1:length(differenceoos)
    if differenceoos(m)>0
        positionoos(m)=1;
    elseif differenceoos(m)<0
        positionoos(m)=-1;
    else
        positionoos(m)=0;
    end
end
feesoos=[1; power(1-fee,abs(diff(positionoos(1:end-1))))];
wealthoos=cumprod((1+returnsoos.*positionoos(1:end-1)).*feesoos);
figure; plot(wealthoos); dateaxis('x',2,'06/13/16')
finalwealthoos=wealthoos(end)
Samplesizeoos=433; AARoos=power(wealthoos(end),252/ Samplesizeoos)-1
```

Program A5 Bollinger bands

```
clear; clc;
importdata('In.xlsx');
price=ans.data;
clear ans;
importdata('Out.xlsx');
priceoos=ans.data;
clear ans;
fee=0.002
returns=price(2:end)./price(1:end-1)-1;
returnsoos=priceoos(2:end)./priceoos(1:end-1)-1;
for a=1:150
    for b=1:0.5:3
        [mid, uppr, lowr]=bollinger(price,a,1,b);
        positions=zeros(size(price));
        for c=1:length(price)
            if price(c)>uppr(c)
                positions(c)=-1;
            elseif price(c)<lowr(c)
                positions(c)=1;
            else
                positions(c)=0;
            end
        end
        position(a,2*b-1,:)=positions;
        fees=[1; power(1-fee,abs(diff(squeeze(position(a,2*b-1,1:end-1)))))];
        wealth(a,2*b-1,:)=cumprod((1+returns.*squeeze(position(a,2*b-1,1:end-
1))).*fees);
    end
```

```
    disp(a)
end
finalwealth=squeeze(wealth(:,:,end));
maxFW=max(max(finalwealth))
figure; contourf(finalwealth);
[midoos, upproos, lowroos]=bollinger(priceoos,12,1,4);
        positionsoos=zeros(size(priceoos));
        for d=1:length(priceoos)
            if priceoos(d)>upproos(d)
                positionsoos(d)=-1;
            elseif priceoos(d)<lowroos(d)
                positionsoos(d)=1;
            else
                positionsoos(d)=0;
            end
        end
feesoos=[1; power(1-fee,abs(diff(squeeze(positionsoos(1:end-1)))))];
wealthoos=cumprod((1+returnsoos.*squeeze(positionsoos(1:end-1))).*feesoos);
finalwealthoos=wealthoos(end)
figure; plot(wealthoos);
dateaxis('x',2,'06/13/16')
Samplesizeoos=433;
AARoos=power(wealthoos(end),252/ Samplesizeoos)-1
```

Program A6 Relative strength index

```
clear; clc;
importdata('In.xlsx');
price=ans.data;
clear ans;
importdata('Out.xlsx');
priceoos=ans.data;
clear ans;
fee=0.002;
returns=price(2:end)./price(1:end-1)-1;
returnsoos=priceoos(2:end)./priceoos(1:end-1)-1;
for a=1:50
    rsi=rsindex(price,a);
    positions=zeros(size(price));
    for i=1:length(rsi)
        if rsi(i)<30
            positions(i)=1;
        elseif rsi(i)>70
            positions(i)=-1;
        else
            positions(i)=0;
        end
    end
    fees=[1; power(1-fee,abs(diff(positions(1:end-1))))];
    wealth(a,:)=cumprod((1+returns.*positions(1:end-1)).*fees);
    disp(a)
end
finalwealth=squeeze(wealth(:,end));
maxFW=max(max(finalwealth))
```

```
figure; plot(1:50,finalwealth);
%Out-of-sample
    rsioos=rsindex(priceoos,32);
    positionsoos=zeros(size(priceoos));
    for m=1:length(rsioos)
        if rsioos(m)<30
            positionsoos(m)=1;
        elseif rsioos(m)>70
            positionsoos(m)=-1;
        else
            positionsoos(m)=0;
        end
    end
feesoos=[1; power(1-fee,abs(diff(positionsoos(1:end-1))))];
wealthoos=cumprod((1+returnsoos.*positionsoos(1:end-1)).*feesoos);
figure; plot(wealthoos);
dateaxis('x',2,'06/13/16')
finalwealthoos=wealthoos(end)
Samplesizeoos=433;
AARoos=power(wealthoos(end),252/ Samplesizeoos)-1
```